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DEPARTMENT OF THE INTERIOR.
HONOURABLE FRANK OLIVER, M.P., MINISTER.

PRELIMINARY REPORT

ON THE

LIMESTONES AND THE LIME INDUSTRY OF MANITOBA

BY

J. WALTER WELLS.

OTTAWA, CANADA.
1905.

Phys. Sci
TN967
C3C35
1905

OTTAWA, May 4th, 1905.

SIR,—

I have the honour to transmit herewith a Preliminary Report on the Limestone and the Lime Industry of Manitoba.

I have the honour to be,

Sir,

Your obedient servant,

(Sgd.) EUGENE HAANEL,
Superintendent of Mines.

HON. FRANK OLIVER, M.P.,
Minister of the Interior.

OTTAWA, 30th March, 1905.

SIR,—

I have the honour to transmit herewith a preliminary report on the Limestones and the Lime Industry of Manitoba. This involves the examination of the limestones, marls and chalk deposits of Manitoba so far as could be done in a preliminary field survey covering a large territory during a period of three months. The report also contains some notes regarding the manufacture and uses of gypsum cement plaster in Manitoba.

I have the honour to be,

Sir,

Your obedient servant,

J. WALTER WELLS.

DR. EUGENE HAANEL,
Superintendent of Mines,
OTTAWA.

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PREFACE.

This report on the limestones, chalks and marls of Manitoba is an attempt to serve the following purposes:—

(1) To give supplementary information to quarry owners concerning the industrial uses of limestones and lime and the qualities which the materials should have to make them valuable for the different applications.

(2) To show consumers of limestone and lime in their various forms the character of the local product.

(3) To show that raw materials for making Portland cement, such as pure limestones, calcareous shales, marls and chalks, exist in Manitoba and to what extent they can be utilized so as to prevent useless expenditure of capital on unsuitable material.

(4) To furnish technical analyses of the limestones to determine their commercial value depending on the composition, thus preventing useless search in unpromising localities.

Five months were spent in the field, assisted for one month by Mr. R. T. Hodgson, a graduate in geology of Queen's University, and all the limestone outcrops convenient to transportation facilities were examined and samples collected for analysis to determine the composition and industrial value of the stone. The chemical work has been ably done by Mr. M. F. Connor, official chemist. The facts are based on personal observation as far as possible.

The writer desires to express his thanks for the many courtesies received while in the field.

OTTAWA, 30th March, 1905.

II.—SOME POINTS REGARDING SEDIMENTARY LIMESTONES.

ORIGIN.

According to origin, limestone may be divided into two classes: (1) *sedimentary,* including those formed in either marine or fresh water either by chemical or organic agents, (2) *crystalline,* including those formed by metamorphic action (heat, pressure and water) from sedimentary limestone or from igneous rocks such as anorthosites, pyroxenites, etc.

All of the limestones having any industrial value in Manitoba are of sedimentary origin, and when the term "limestone" is hereafter mentioned it refers to the sedimentary variety unless otherwise specified.

It is impossible in this report to discuss the different methods by which limestone has been or is being formed under natural conditions.

The calcareous remains of organisms such as the corals, molluscs and the foraminifera have been the chief source of limestone by having their shells ground to a calcareous slime before deposition. A deposit of cretaceous limestone on the banks of the Assiniboine River consists of crushed oyster shells cemented into a hard, gray limestone.

Those laid down by chemical precipitation in deep water, such as in Upper Devonian periods, are likely to be quite pure, while those laid down from concentrated solutions are likely to contain magnesia, for example, the dolomites of the Niagara formation in the Silurian period.

Those laid down in shallow water are often clay-bearing and pass insensibly into calcareous shales, for example, a deposit of chalk of the Niobrara formation in the Cretaceous period was noted on the banks of the Pembina River adjacent to deposits of calcareous shale consisting of the remains of minute forminifera and radiolaria imbedded as small white specks in the gray shale.

One process of formation may be seen in the beds of marl at the bottom of lakes and bogs in limestone areas.

Sedimentary limestones are often changed to the *crystalline variety* or marble by intrusions of dikes and other rock masses of igneous origin, thereby losing their bedded structure and contained fossils.

GEOLOGICAL OCCURRENCE.

Bedded limestones may be found in all geological periods from the Silurian up to and including the Cretaceous.

CHEMICAL COMPOSITION.

Pure limestone consists of carbonate of lime united in the proportion of 56% of oxide of lime and 44% of carbon dioxide.

Pure limestone is rarely found under natural conditions, the impurities seldom being less than 1%, while they may be so abundant as to prohibit calling the rock a limestone. The common impurities are silica, iron, alumina, magnesia, organic matter, alkalis and traces of sulphuric acid.

The silica may be present as free sand, combined with alumina, in the form of clay or as a constituent of silicates, such as mica or hornblende. Alumina is generally present as a constituent of clay, and when the clay is present in noticeable quantity, the limestone passes into cement rock.

Iron is always present in small or large quantity, as ferric oxide, as carbonate of iron, or as pyrites (sulphide of iron).

Magnesia is a common constituent of limestone. When 20% or more of magnesia is present the stone may be classed as dolomite. Organic matter is generally present in limestone, giving the stone a color varying from gray to black.

The impurities play an important part in the industrial uses of limestone, as will be later shown, where its chemical properties are utilized.

Limestones are usually divided into two classes—lime rock and cement rock—which grade into each other. When the former is calcined, it slakes or crumbles in water with evolution of heat. The latter when calcined does not slake, but forms a hard mass on the addition of water.

The following classification is based on the chemical composition and uses of limestone:—

Limestones	Lime Rocks	Limestone, more or less pure, Magnesian limestone, Dolomite,
	Hydraulic Lime and Cement Rocks	Argillaceous limestone, Argillaceous magnesian limestone.

MINERALOGICAL COMPOSITION.

Pure limestone contains only carbonate of lime, but as found under natural conditions it carries impurities. The commonest of these is silica, which may be present as small grains or as nodules of cherty silica commonly known as flint. When such an impure limestone is exposed to the action of the weather the siliceous spots or layers stand out in relief on the weathered surface so that a weathered surface is often a guide as to the siliceous impurities which the rock contains.

The amount of siliceous matter may vary from traces to 50%; in the latter case the stone may be classed either as a sandy limestone or as a calcareous sandstone. An example of such a transition may be seen at Grindstone Point on the west shore of Lake Winnipeg.

Bedded limestone often contains clay more or less evenly distributed through the rock. Such argillaceous or clay-bearing limestone is found at Queenston and Thorold, Ontario, also at Kingston, Ontario. The writer did not notice argillaceous limestone in Manitoba.

Iron, either as a carbonate or as ferric oxide often acting as a cementing material, is usually found in limestones of all formations. Sulphide of iron as nodular pyrite was noted in the chalk beds of the Cretaceous formation in Manitoba.

Gypsum (sulphate of lime) is sometimes found in limestones of sedimentary origin. Other minerals such as barite (sulphate of barium), witherite (carbonate of barium) may be found either finely disseminated through the rock or as segregations.

Natural bedded limestone usually carries carbonate of magnesia, especially when thrown down from concentrated solutions, as in the Upper Silurian period.

Limestones which have undergone a contact or regional metamorphism are usually coarsely crystalline in texture, and contain such minerals as horneblende, garnet, amphibole, vesuvianite, graphite, etc. Crystalline limestone may carry more or less carbonate of magnesia.

COLOR.

A perfectly pure limestone would be white, but they are usually colored either by organic matter or iron oxides. Organic matter imparts to limestones a color varying from gray to black.

Oxides of iron impart colors varying from cream, yellow, red or brown, depending on the form of combination and the state of oxidization of the contained iron. A reddish dolomite containing a large quantity of oxide of iron was noted about 2 miles west of Sawdust Island and ½-mile back from the east shore of Lake Manitoba.

TEXTURE.

Bedded or sedimentary limestones are commonly fine grained, but may vary from fine earthy to coarse grained rocks.

Metamorphosed limestones are often coarsely crystalline, but generally compact. The hardness of the rock seems to depend partly on the cementing material which binds the grains together and partly on the shape of the grains, whether rounded or angular, the latter having a tendency to interlock.

The limestones in the Stonewall district have irregular vesicles or pits, but nevertheless they are harder than the Tyndal stone which has a more compact texture. The relative hardness of limestones may effect their commercial value. If too soft they are unsuitable for cut stone and when crushed, they make a fine dust useless for rubble and concrete and are liable to pulverize in burning. If too hard, the increase in the cost of quarrying and dressing the stone for building purposes may be prohibitory as in the case of the Stonewall quarries. Hard limestones are also difficult to burn into quicklime.

Limestones often carry layers of sand, cherty nodules, or in some cases silicified fossils. If a siliceous variety must be used, it is better for all purposes to select those having the siliceous matter evenly distributed.

WEATHERING QUALITIES.

The appearance of the faces of natural outcrops of limestone is often a good indication of the weathering qualities of the stone as applied to its use as a cut stone for building purposes. The weathering qualities depend on the presence of impurities and the structure of the stone.

III.—SOME USES OF LIMESTONE AS APPLIED TO MANITOBA.

Limestone either in its raw or burned state has found many uses in the industrial arts and the rapid development of new industries in which it is used gives a new interest to this common mineral.

The use of limestone as a building material in various forms, such as cut stone, rubble, crushed stone, etc., is well developed in Manitoba so that only certain new uses which may be introduced will be described. The uses of limestone for making ordinary quicklime and hydraulic lime are described under the heading "Lime and Lime-burning."

PAPER MAKING.

In the eastern portions of Manitoba and in western Ontario there are large tracts of spruce and poplar suitable for conversion into chemical wood pulp for use in paper making.

Deposits of pyrite (sulphide of iron) are known to exist north of Wabigoon Station, C.P.R., but of no commercial value as they are too remote from the present market. It may be possible to combine at Keewatin or Rat Portage the sulphur ores of western Ontario with the Tyndal limestone to make sulphite of lime for chemical wood pulp.

For making sulphite of lime according to present methods the limestone must be free from iron (less than 1%), as this causes discoloration of the pulp. The presence of magnesia is desirable, in fact the higher the percentage of magnesia the more desirable the stone. Different methods are employed to make sulphite of lime, but the following brief description gives the principle of manufacture.

Cylinders 5 feet in diameter and 100 feet high are filled with crushed limestone, preferably dolomite. Fumes of sulphurous acid (SO_2), obtained by burning pyrite (sulphide of iron), are introduced at the bottom and water is allowed to trickle down from the top. The stone is slowly dissolved and the sulphite liquor is drawn off into storage tanks.

The wood is chipped into pieces about 1 inch long and placed in digesters, being tall cylinders lined with acid-proof brick. The sulphite liquor is then introduced and the mixture heated by steam under pressure for several hours. The chips come out, after washing in clean water, as white fibre free from pitch and all discolorations.

For soda pulp, that is wood pulp made by digesting the wood in a solution of caustic soda, any ordinary good limestone will give a quicklime suitable for causticising the carbonate of soda.

GLASS-MAKING.

It may prove a profitable business in Manitoba to convert the limestone and fine sand of proper quality found together near railway facilities into common glassware, such as bottles, fruit jars, insulators, etc. Next to silica, lime is the most important of materials for glass making, as it renders the soda and potash less soluble and facilitates fusion.

The lime contained in glass is commonly added to the mixture in the form of finely crushed limestone, this being preferable to quicklime which may change in composition by absorption of carbon dioxide and water from the air. Limestone containing much iron oxide should be avoided, as it colors the glass. Magnesia makes the glass less fusable, but dolomite is often employed. The sand at Bird's Hill and Gonor may be suitable for glass in combination with the Tyndal limestone.

FURNACE FLUX.

A common use for limestone is as a flux, both for iron and lead ores. In the blast furnace it aids in reducing the iron to its metallic state by fluxing off the impurities as slag. Limestone in excess purifies the pig-iron from sulphur and also prevents the reduction of silica ($Si0_2$) to silicon (Si).

The purer the limestone the more efficient will be its action and the cheaper its use, since the greater the impurities present the more limestone will be needed to flux off the impurities.

Iron ore is known to exist in the Lake Winnipeg district as magnetic sands on the east shore and as hematite on Black Island and possibly charcoal iron may be made in that district at some future date.

ROAD-MAKING MATERIAL.

Hard and tough limestone crushed to sizes varying from ¼ to 2 inches in diameter is a cheap and efficient road-making material and railroad ballast which should come into more extensive use in Manitoba, especially in those parts where gravel is not available. It is certain that both country and city roads in Manitoba would be much improved by its use.

HYDRAULIC CEMENT.

Limestones carrying 6% or more clay, when properly burned, produce hydraulic limes and cements. There is no hard and fast distinction between these two materials except that the cements have stronger setting qualities. Hydraulic limes are discussed under the heading of lime and lime burning.

Hydraulic Cement, as used in an engineering sense, means such a chemical combination of alumina, lime, silica and iron which when properly powdered and mixed with the proper amount of water has the property of hardening under water without noticeable change of volume or evolution of heat. It has also the property of hardening when in contact with moist air.

Natural hydraulic cement is made in Manitoba, and the raw materials for Portland Cement are available. (See Report on the Cement Industry of Manitoba).

MINOR USES.

Other uses of limestone not specially applicable in Manitoba are for carbide of lime used to generate acetylene gas, in purifying raw sugar, in the manufacture of soda from common salt by the Le Blanc and Solvay methods, in generating carbonic acid gas used in carbonating beverages, in the manufacture of chloride of lime and also sulphate of lime used as a filler in paper making.

Dolomite is used as a furnace lining for basic steel furnaces. It may also be used to produce Epsom salts or sulphate of magnesium, but magnesite (carbonate of magnesia) is preferable for this purpose as the lime present in dolomite produces lime sulphate which is an insoluble compound clogging the working of the sulphuric acid on the raw stone.

IV.—LIME AND LIME BURNING.

Lime or calcium oxide, not existing as such in nature, is made by heating to a red heat any form of lime carbonate, such as bedded limestone, marble, calcite, chalk or marl, which undergoes dissociation thus:—

$\mathrm{CaCO_3}$	+	heat	=	CaO	+	$\mathrm{CO_2}$
lime carbonate				lime oxide, quick lime, caustic lime.		carbon dioxide, carbonic acid gas.

The carbon dioxide is driven off as a gas and the lime oxide remains as a powdery or lumpy material, usually white in color, but may be gray or cream colored, according to impurities present.

Pure limestone heated in a platinum crucible loses some of its carbon dioxide at 750° Fahrenheit, and all of it at a temperature of 1,400° F.

COMPOSITION OF LIME STONES FOR LIME-BURNING.

Many different varieties of limestones, such as bedded limestone and marble, are suitable for burning into lime; those only being excluded which contain a large quantity of clay, silica in the form of sand and flint nodules, or iron, as these impurities affect the important industrial properties of lime.

Limestones carrying 8% or more of clay will burn to a brownish gray lime more or less sintered and on the addition of water the material does not slake completely but partly sets into a hard mass and is known as hydraulic lime.

Many of the limestones in the Lake Winnipeg district are unfit for lime-burning on account of contained nodules of cherty silica known locally as flint, which remain intact when water is added to the burned limestone.

Finely divided silica when evenly distributed through limestone in quantities of 10% or more imparts hydraulic properties to thelime made from such impure stone.

Iron either as oxides, carbonates, or pyrites, in limestone imparts to the burnt lime a creamy or red color.

Magnesia cannot be considered an impurity in limestone used for burning into ordinary lime. The presence of more than 20% magnesia renders quicklime slower in slaking so that it will stand storage with less deterioration than high calcium limes.

The Stonewall lime burners produce a fair quality of magnesian lime from dolomite carrying an average of 54% lime carbonate and 45% magnesium carbonate.

SOME POINTS IN LIME BURNING.

A compact limestone is much harder to burn than those of loose texture and more fuel is required, but the quality and quantity of lime produced more than counterbalances the cost of fuel. In a pure compact limestone the percentage of quicklime may be 54% while in an impure one it may be only 30%.

Frasch states (Mineral Industry, 1899, page 484) the following yield of quicklime from limestone of different grades:..

Limestone	95%	pure yields	59%	burnt lime,	90%	CaO.
"	90%	"	60%	"	80%	"
"	85%	"	65.5%	"	72%	"
"	80%	"	70%	"	64%	"

The time required for the burning is dependent upon the size and compactness of the stone and also on the moisture content, for water aids to a certain extent in carrying off the carbon dioxide and hastens the burning, so that freshly quarried stone can be burned quickly as it has not lost its quarry moisture. Periodical injections of steam or water into the kiln are recommended but not always necessary in the case of kilns heated by grate fires at the bottom of the kiln.

Limestone carrying silica and alumina evenly distibuted through the rock should be burned with a moderate heat as a high heat will cause the pieces to fuse on the outside, preventing the escape of the carbonic acid and resulting in "dead-burnt" lime which does not slake completely.

It is stated that the best limestone, if burned at a high heat, but not long enough, may yield "dead-burnt" lime, in which case a basic lime carbonate ($CaO, CaCO_3$) is formed which with water forms a mixture of lime carbonate and lime hydrate and hardens.

TYPES OF LIME KILNS.

The kilns at present used by Canadian lime burners are more or less similar in construction, the general principle of construction being that of a cylindrical, vertical shaft, lined with fire brick, open at the top and narrowing at the bottom to a discharge opening.

Lime kilns are either intermittent or continuous in their working. The style of kiln most suitable depends on the kind of fuel available, and also on the quantity and quality of lime to be produced.

In the operation of *intermittent kilns without fire-places* the limestone is put into the kiln with alternate layers of fuel till the kiln is full. The fire is lighted and allowed to burn itself out. The kiln is allowed to cool for 12 hours or more and the burned stone is drawn off at the bottom. Such kilns, in which the fuel is charged with the rock, are cheap to construct and give a large output in a short time with a small consumption of fuel. For these kilns the rock should be of small size (7 inches and less in diameter) since the burning is done quickly.

The lime produced is generally inferior in quality, as it is likely to be partly overburned and partly underburned and gray in color, owing to the mixture of ashes from the fuel, but is suitable for ordinary purposes except when a white quick-slaking lime is required. Bituminous coal and lignite are the common fuels employed.

A common form of vertical intermittent kiln used in Ontario and Manitoba is the *pot kiln,* which may be built on the face of the quarry, as shown in Plate No. 1, or constructed of rough dressed stone alongside the railway spur running into the quarry, as shown in Plate No. 5.

The kiln may be lined with fire-brick, but in Manitoba small granite boulders are employed using clay as a bond, which together with the burnt lime forms a solid mass of fire-proof cement. Such kilns are fired with wood from the fire-place at the bottom of the kiln nearest the railway track and the firing usually takes from 3 to 4 days. The arch over the fire-place is usually built on a steel rail with two moveable cross rails to keep the stone from falling through into the fire pit.

Such kilns are cheap to construct and also to operate, where cheap wood is available and where the demand, as in Manitoba, is only for a few months during the year.

Continuous Kilns without Fire-places, as shown in plate No. 6, in which the fuel is charged together with the limestone, are used in burning lime and also for making natural rock cement from argillaceous magnesian limestone.

Such kilns are constructed of ½-inch boiler plate lined with fire-brick, the cylindrical shaft being about 7 feet in diameter and 40 feet high. In the kiln, as shown in Plate No. 6, which is used at Arnold, Manitoba, for making natural cement from calcareous shale, the fuel (Estevan lignite) is charged from a car running on a level with the top of the kiln, while the shale is hoisted by a bucket elevator. The burnt rock is drawn out on two platforms and may be shovelled into cars running underneath. Such a kiln is cheap to construct, utilizes most of the heating power of the coal and gives a large output in a short time with small consumption of fuel.

However, overburning of the lime cannot be avoided so that the silica usually found in limestone and the ash from the fuel unite with lime forming vitreous silicates of lime which do not slake quickly like quicklime but only after the lapse of a few months when the plaster or mortar made from the lime cracks, causing an unsightly appearance on the walls of buildings.

Continuous kilns with the draw opening below the fire-place, as shown in Plate No. 3, are commonly used in Ontario and in Manitoba the writer saw five such kilns built up of rough dressed quarry stone about 40 feet high and lined with fire brick. The limestone is charged at the top, as required, and firing is done at the side opening, using tamarac and other soft wood as fuel, while the burnt lime is removed at the bottom.

In these kilns a high even temperature can be obtained in the body of the kiln with a small amount of fuel as the air passing through the draw-opening at the bottom cools the hot lime and is itself heated.

Draw kilns using coal as fuel are now being equipped in the United States with the Eldred flame regulator apparatus and the following description serves to show the principle of the process, further particulars being obtainable from the Eldred Process Company, 208 Fifth Avenue, New York City.

The type of apparatus used is shown in Plate No. 7, *G* being the fire place communicating with the shaft of the kiln *A* through an opening or arch. *J* and *K* are the fire and ash-pit openings, provided with suitable doors. *L* is the draw-opening for removing the lime. A draft pipe connects at the upper end with *A*, through opening *C*, and at its lower end with the ash-pit *B*, through opening *E*, and has interposed in it a fan-blower *D*. That part of the conduit above the fan constitutes the suction pipe of said fan, and the part below the fan constitutes a delivery pipe controlled by the gate or valve *H*. The fan has also an auxiliary outlet or delivery pipe *I*, controlled by a gate or valve through which a portion of the kiln gases may be disposed of without causing them to pass through the fire. At *F* the suction pipe is provided with an air inlet, also controlled by a valve. By adjusting this valve the relative proportion of air and kiln-gases in the draft may be exactly controlled.

The Eldred process involves a cyclic return of a portion of the heated waste gases admitting sufficient oxygen to the coal in the grate, while the non-combustible gases may be used to retard combustion in the grate and carry the generation of the heat into the body of the kiln where it is needed.

The fire is tempered to the proper calcination point and the volume of the flame entering the kiln is increased so that the output of the kiln shows a gain of 50% and more over the ordinary method of coal firing, while there is no danger of overburning the lime owing to the volumiuous flame of low regular intensity producing uniform calcination of the limestone.

In a lime kiln equipped with the Eldred flame regulation apparatus the gases carry the heat in potential form and evolve it where it is needed, giving the process a decided advantage over the ordinary process of lime-burning where the heating is done partly by convection but mostly by conduction. The process is flexible and by proper adjustment the flame may be varied from the localized intense heat of the ordinary forced draft of pure air to a voluminous, slow, regular flame of low intensity, only sufficient to char wood.

RESULTS OBTAINED WITH THE ELDRED PROCESS IN LIME-BURNING.

By using the Eldred process a ton of coal is said to produce more than twice the amount of lime that is now produced from a cord of wood. One lime-burner reports a saving of $50 per week per kiln by the use of the process, while an average output of 200 barrels per day of lime has been obtained from a single kiln burning dolomite rock.

The Eldred process gives an average efficiency of 5 pounds of lime per pound of coal burned. This means that about 85% of the heat energy of the coal is used in the actual calcination of the limestone, while about 15% is lost in the sensible heat of the escaping gases and through radiation.

It would be a useful point to know how far air dried peat, obtained from the Julius bog near Molson and the St. Andrew's bog near Stony Mountain and also waste lignite fines from the Estevan lignite mines could be used as a fuel by this process of lime burning.

It may be profitable to apply this fuel-saving process at the following points:—

(1) At the Garson Quarry, Tyndal, using Estevan lignite coal as fuel,
(2) At the Landing, using limestone from Lake Manitoba with Estevan lignite coal as fuel,
(3) At Winnipegosis, using the local limestone with Edmonton lignite coal as fuel,
(4) At Kanaskasis Limestone Quarries, Alberta, using Banff coal as fuel.

SOME PROPERTIES OF QUICKLIME.

Quicklime obtained by the burning of limestone is a white, amorphous, infusible mass with a specific gravity of about 3.09 (water = 1).

It absorbs moisture and carbon dioxide rapidly when placed in moist air, slaking to a gritty powder of hydrated basic carbonate of lime, which is useless for mortar. Hence quicklime should be stored in dry air.

Well burned pure lime slakes to a fine powder on adding one-third of its weight of water, forming hydrate or hydroxide of lime (CaO_2H_2) which has a specific gravity of 2.07.

The lime first absorbs the water and then chemically combines with the water, increasing in volume about three-fold, with evolution of heat often so great as to char wood, so that it is inadvisable to pack pure quicklime in wooden barrels.

Depending on the amount of clay and siliceous impurities present, artificial limes suitable for mortar may be divided into the following classes:—

(1) *Common or fat Limes,* containing less than 10% of impurities, not including magnesia, which cannot be called an impurity of lime for mortar.

Mortar made from fat lime and sand does not harden under water but hardens in air with slight shrinkage.

(2) *Hydraulic Limes,* containing from 10 to 35% of clay and siliceous impurities, slaking slowly and hardening under water.

(3) *Natural Hydraulic Cements,* containing about 35% lime, mostly combined with silica and alumina, not slaking on the addition of water, but setting under water into a hard mass. Obtained by calcining argillaceous limestones.

(4) *Artificial Hydraulic Cements,* containing from 60 to 65% lime which should be all combined with alumina and silica, not slaking on addition of water but setting into a hard mass, obtained by burning artificial mixtures of clay and carbonate of lime at a high heat.

The magnesian limes do not come within the class ranging from pure lime down to Portland cement. Magnesia cannot be considered an impurity of lime when used for mortar and plaster. As produced in the ordinary process of lime burning it has little chemical affinity for water, hence a quicklime containing a large proportion of magnesia is slow slaking, producing a smaller quantity of lime paste or putty than quicklime largely made up of calcium oxide. Magnesia, though inert in slaking, is very active in setting and, according to several authorities as reported in technical journals, the magnesia lime when used neat will have 50% greater strength than the high calcium one; in the case of sand mixtures it will carry about 50% more sand than high calcium lime to produce a mortar of the same consistency and strength.

The writer has noted the great cementing power of magnesia in the manufacture of artificial marble made from magnesium oxychloride cement and sand by a well-known formula.

So that in practical use a high calcium quicklime is specially adapted for use in the finishing coat for wall plaster where ultimate strength is not essential.

On the contrary, high magnesian quicklime is considered to be cheaper and better for sand mixtures, such as back plaster and ordinary mortar. Owing to its slow slaking quality it will stand longer storage without deterioration.

HYDRATED LIME.

Hydrated lime is now produced as a dry white amorphous powder and is simply quicklime treated with just enough water to chemically satisfy its demands, about 9 pounds of water uniting with each 28 pounds of quicklime, causing the lime to swell to about three times its original bulk and then crumble into a powder. If less water be given it, then some of the quicklime will remain unacted upon. If more water be given than is chemically required, excess moisture is present as a mechanical and less water will be required to turn the product into paste.

The amount of water required for hydration depends on the percentage of lime oxide (CaO), the only chemically active element of any lime so far as water combination is concerned.

METHOD OF MANUFACTURE.

Hydrated lime is commercially prepared by slaking quicklime to a putty or paste which may be dried by incorporating ground quicklime to absorb the excess of water.

The product is a dry, white, powdered, completely slaked lime, which will not absorb water and carbon dioxide from the air under ordinary conditions of storage.

The following American engineering companies furnish hydrating plants:—

(1) Eldred Process Company, 208 Fifth Avenue, New York City.
(2) Clyde Iron Works, Duluth, Minnesota.
(3) American Hydrating Company, Delaware, Ohio.
(4) National New Process Lime Company, 39 Cortlandt Street, New York City.

In any hydrating process the following points are essential:—

(1) Grinding the lump lime to an uniform fine powder so that each particle may combine with the necessary quantity of water.

(2) The quicklime should be handled in batches, each being weighed. The proper weight of water dependent on the chemical analysis of the lime should then be quickly added and thoroughly mixed.

(3) Special mixing machinery is required and the time depends on the quicklime as magnesian limes are slower slaking than high calcium limes.

(4) Considerable time must be allowed for tempering and steaming the mixture in large vats so that no free lime will be present.

(5) The product should be carefully screened from all free impurities to a fineness of at least 50 mesh.

PRACTICAL USES OF HYDRATED LIME.

Hydrated lime has the following advantages over ordinary quicklime:

(1) It is a dry staple commodity which may be shipped and stored in paper bags without fear of swelling.

(2) It is unaffected by air slaking and is subject only to such deterioration in storage as affects cement.

(3) It is a purer product reduced to an impalpable powder fit for many uses in the chemical industries, since it is free from coarse particles of unburned stone, sand, cinder, ash, etc., eliminated in the screening process.

(4) It is always ready for use and when water is added heat is not evolved and the resulting lime paste is the same no matter whether the hydrated lime is ten years old or just made from fresh quicklime.

(5) Reports state that pound for pound it will carry as much sand as fresh quicklime, probably due to the fact that it is finely ground. It seems to work as smoothly under the trowel as ordinary lime.

(6) Mortar may be prepared by a dry mixture which is ready for use on the addition of water.

A mixture of Portland cement and hydrated lime is now being used as a hard wall plaster, producing a strong, dense, water-proof, smooth finish not affected by atmospheric changes of heat and moisture.

If Portland cement and hydrated lime are mixed in equal proportions, the mixture can be used as a cementing material to make a mortar of ordinary strength equal to a mortar made of natural cement with an equivalent proportion of sand. It is claimed that the Portland cement-lime mortar is cheaper. The use of a small quantity of hydrated lime in cement concrete makes it moisture proof.

V.—SOME USES OF LIME AS APPLIED TO MANITOBA.

LIME—MORTAR.

Lime-mortar is a mixture of slaked lime, sand and water used to bind together masonry of brick and stone. It is the cheapest form of mortar that can be used in Manitoba, but is not suitable for use in damp places, such as foundations and cellar walls.

Gilmore states (Limes, Hydraulic Cements and Mortars, page 299) that the lime in mortar forms silicate, carbonate and hydrate of lime and the crystals of these compounds interlock with the grains of sand, thus binding the whole together into a solid mass. In the course of time all the lime changes to carbonate.

Richardson states (Brick-builder, 1897, page 78) the following requirements for caustic lime when used for mortar:—

1. It should slake rapidly, showing that it is rich and fresh.
2. It should contain less than 10% of impurities, but often has more.
3. It should be white or nearly so in color. Lime of a yellow or brownish color with veins of siliceous matter is inferior.
4. It should be free from fused or semi-fused stone which shows over-burning and also from unburnt ash of fuel or clinker.
5. Except when made from coarsely crystalline marble or from marl or shells it should be in hard lumps.
6. Sand is added to lime for economy and to prevent shrinkage. Sand should be clean and sharp and in such quantity that the lime will fill all the interstices. If an excess of sand is used, the bond is poor. If too little sand is used, the mortar shrinks and cracks. If too little lime is used the paste is made thin. Popping of mortar is due to particles of unslaked lime.

PORTLAND CEMENT-LIME MORTAR.

Lime is often used in Portland Cement Mortar for several reasons. There are many kinds of work which require a quick-hardening mortar, but for which the great strength of a mixture of 1 part of cement with 4 of sand is not required. The cost of such cement mortar is also too high for many purposes. A mixture of 1 part of cement with 5 or more parts sand would give sufficient strength, but, according to practical masons, such mortar works harsh and brittle, adhering imperfectly to the brick or stone, and the addition of lime paste or hydrated lime to the mortar "gives it body" and makes it "work smoothly" under the trowel.

ARTIFICIAL STONE.

The use of hydrated lime mixed with Portland cement for producing water-proof concrete work and artificial stone building blocks seems to be coming into extensive use, especially for foundations, cellars and external walls. If constructed of ordinary Portland cement concrete they are liable to absorb and retain moisture.

The lime must be pure and slaked completely so that no granular particles of free lime remain in the powder, as these are liable to blow the concrete in which hydrated lime is used.

Hydrated lime will not swell or expand in the finished concrete as free lime does in concrete after it has set and hardened, causing internal stresses, producing cracks and blow-holes on the surface.

The addition of about 15 pounds of hydrated lime to each 100 pounds of Portland cement mixed to a uniform color just before the gravel or crushed stone is added produces a dense and water-proof artificial stone or concrete.

SAND-LIME PRESSED BRICK.

This industry started about ten years ago in Germany, where, according to reports, about 90 factories produced in the year 1902 more than 400,000,000 sand-lime pressed bricks. It is being rapidly introduced in the United States and already there are four plants in Canada. It should be successful in Manitoba where lime and sand are convenient to shipping facilities.

Beds of fine sand were noted by the writer in Manitoba close to the railway tracks at Gonor, Bird's Hill, east of Saint Anne's, north of Molson, near Carberry, west of Brandon, between Miami and Arnold and deposits of suitable sand can be found at other points.

Tyndal lime carries about 8% magnesia and should be suitable for sand-lime pressed brick especially if converted into hydrated lime before use.

METHOD OF MANUFACTURE.

It is impossible in this report to describe the different methods of making sand-lime pressed brick, but the following points are essential in any process:—

(1) A cheap, abundant supply of clean, dry sand, as fine grained as possible.
(2) Finely divided lime, preferably dry hydrated lime, containing a low percentage of magnesia.
(3) A thorough blending of the raw materials, mixed in the proportion of not more than 14 parts of sand to 1 of hydrated lime.
(4) The addition of water to the mixture, just sufficient to make a coherent brick.
(5) Strong pressure in moulding the brick.
(6) Heating the raw brick in a closed cylinder with superheated steam under a pressure of 120 pounds or more for a period of 12 hours ~~or more~~. 10

The object of the process is to form a chemical combination of the lime and sand into silicates and hydro-silicates of lime, making a cheap, strong, tough, compact brick for ordinary building purposes, standing all conditions of the weather, not absorbing water and resisting the action of fire.

Sand-lime bricks are made at Ottawa in competition with ordinary and pressed clay brick and the product appears to stand all conditions of the weather without injury. A sample selected from the pile at the factory subjected to weathering for several months without injury gave the following results on alysis:—

Moisture	0.45
Insoluble (sand)	78.40
Alumina and iron oxides	3.00
Lime	10.14
Magnesia	0.64
Sulphur trioxide	0.15
Undetermined { combined water carbon dioxide }	7.22
	100.00

The results show that the lime used constitutes about 10% of the whole brick, and contains a very small quantity of magnesia.

In some of the processes better results are claimed by the addition of chemicals such as common salt, carbonate of soda, carbonate of potash, soluble glass (silicate of soda and potash), each of which under proper conditions may produce more or less combination of the lime and sand but at an increased expense.

It is claimed that magnesian lime, such as produced by the lime kilns in Manitoba, has its binding or cementing power greatly improved by the use of small quantities of calcium chloride, a cheap chemical known commercially as chloride of lime.

The process consists in forming basic carbonate of lime and oxychloride of magnesium by the admixture of calcium chloride, increasing the hardness and cementing properties of the lime which is desirable in making sand-lime brick.

In one patented process a warm dilute solution of calcium-chloride is added to a mixture of carefully sifted sand and quicklime, producing a plastic mass which can be moulded and then hardened by steam under pressure. It is claimed that by this process not only is the lime slaked completely, but the thermo-chemical effect due to the slaking tends to assist the combination of the sand and lime, also increasing the plasticity and cohesion of the mixture to an extent sufficient to allow of working the mass.

BRANDON SAND-LIME BRICK WORKS.

The plant is located at a sand hill about 1 mile west of Brandon City and at the time of inspection (November 11th) was producing a fair grade of cream-colored pressed brick for facings and a softer second grade suitable for interior walls. The bricks are said to stand weather conditions in Manitoba and also are fire-proof and suitable for facing and backing brick for walls, sewer brick, linings for wells, as a substitute for fire-brick and for ordinary uses where clay bricks are employed. They do not seem suitable for street pavements.

The Huennekes system is used and the plant is rather badly arranged. The sand is delivered to a horizontal drying chamber lined with steam pipes and when dried conveyed by a belt conveyor to a tilted tube mill where it is mixed with lime from the
Tyndal lime kilns in approximate proportions of ~~12~~ parts of sand 95
5 to ~~1~~ of lime. Water is added to slake the lime, the heat generated
assisting in the combination of the lime and sand. The tube mill
makes 26 revolutions per minute and a run of ~~6~~ hours is sufficient 10
aterial for to make 15,000 bricks. The mixture is elevated to a storage bin
from which it is fed by gravity to a Chisholm and Boyd press,
3 making ~~6~~ bricks at onepressing. The pressed bricks are loaded ona
truck and passed to a steam cylinder ~~about 100~~ feet long, where they 60
are subjected to steam at 120 pounds pressure for ~~12~~ hours ormore. 10
Plate No. 8 shows the method of operation of pressing ~~and steamin~~g.

Attempts were made to assist the combination of lime and sand by adding salt, carbonate of soda and carbonate of potash at an increased expense with more or less success.

The use of chloride of lime is recommended for this purpose, as already noted.

The advantages of sand-lime brick in Manitoba over common clay brick are said to be:—

(1) They can be made in 10 hours and at all seasons of the year, with little handling and no skilled labor except the foreman and engineer.
(2) They are cheaper than clay brick where sand is abundant, requiring small expense for fuel, as they are not burned.
(3) They can be laid in the wall the day after they are made.
(4) Any color required is made by the admixture of cheap dry pigments.
(5) They are of uniform size.

HARD WALL PLASTER.

A large quantity of lime is used in Manitoba as a wall plaster for the interior houses, of although gypsum cement plaster as made by the Manitoba Union Mining Company is rapidly taking its place, as it gives a superior finish and can be used in cold weather.

It is claimed that a superior hard plaster can be made from sand and dolomite or magnesian lime, when treated by the Cappon process, which consists in forming basic carbonate of lime and oxychloride of magnesium by mixing calcium chloride ($CaCl_2$) to the lime, increasing both the hardness and the cementing quality of the lime. The calcium chloride must be pure but is fortunately a cheap chemical.

Its use in lime mortar has the further advantage that the freezing point is lowered even more than by the use of common salt.

It is also claimed that a mixture of hydrated lime and Portland cement makes a superior hard wall plaster, already noted.

ROUGH PLASTER.

A good rough plaster is made in Manitoba from slaked lime, sand or gravel and water and is used for rough-cast houses and stables, apparently standing weather conditions.

WATER-SOFTENING.

Lime has been used for many years to remove soluble lime and magnesia salts from alkaline waters, both for drinking and manufacturing purposes.

For this purpose the lime must be as pure as possible. The reaction taking place for removing lime is thus:—

$$\begin{array}{ccccccc} CaH_2\,(CO_3)_2 & + & Ca\,(OH)_2 & = & 2\,CaCO_3 & + & 2\,H_2O \\ \text{bicarbonate of} & & \text{hydrate of} & & \text{lime} & & \text{water.} \\ \text{lime.} & & \text{lime.} & & \text{carbonate.} & & \end{array}$$

Both the lime in solution as a bicarbonate and that added as hydrate are precipitated as insoluble lime carbonate. Bicarbonate of magnesia is not entirely removed from the water by this method.

Clear lime water is used to remove the soluble lime and magnesia compounds as it is easily controlled and an excess can be avoided. The precipitate of lime carbonate is removed by passing the water after treatment through filter cloths and into settling tanks.

The City of Winnipeg owns a water-softening plant which is said to have cost about $100,000. The lime used is of American manufacture, costing $18.00 per ton laid down at the plant.

The following analysis of a sample selected by the writer at the plant shows it to be high grade:—

	Silica	0.89
	Alumina Iron oxide	0.77
	Lime	72.17
	Magnesia	0.50
	Sulphuric anhydride	0.10
Loss on ignition	Carbon dioxide Water in combination Water as moisture	24.50
	Undetermined	1.07
		100.00

This material is expensive and the lime burners in Manitoba are anxious to get a pure limestone for burning into a high grade quicklime suitable for this purpose and for sand-lime brick. The limestone found at Steep Rock on the east shore of Lake Manitoba and in the Upper Devonian areas in north-western Manitoba may fill the requirements.

The lime now produced in Manitoba contains 8% or more of magnesia, rendering it unfit for water-softening purposes. It is possible by chemical agents to remove magnesia from quicklime on a commercial scale, but it would not be a profitable business in Manitoba.

SOAP.

In the manufacture of soap slaked lime is used to produce caustic soda (NaOH) from soda ash (Na_2CO_3). The two are mixed with water and boiled with steam, forming a solution of caustic soda and insoluble lime carbonate which is removed by settling in tanks. For this purpose the lime should be as pure as possible.

In the manufacture of stearin for candles, ordinary tallow is boiled in wooden vats by high pressure steam with slaked lime for several hours, forming lime soap or stearate of lime. This is transferred to another vat and treated with dilute sulphuric acid which combines with the lime to form insoluble sulphate of lime, settling to the bottom of the vat while the fatty acids rise to the surface. For this purpose a pure quicklime is desirable.

Soap making as a branch of the meat packing industry is likely to be a profitable business in Western Canada.

TANNING.

In tanning hides for leather the hair is removed from the hides by soaking with slaked lime in vats or pits. For this purpose ordinary lime is suitable.

STRAW-BOARD PULP AND PAPER.

An immense quantity of wheat and oat straw is produced in Manitoba and most of it is burned in piles in the open field.

This straw is suitable, either alone or mixed with other fibres such as wood pulp, flax straw, jute, etcetera, for conversion into straw-board pulp and paper for the manufacture of paper boxes, coarse wrapping papers, sheeting and tarred papers for houses, artificial lath and wall board combined with hard wall plaster.

One stage in the manufacture of straw-board pulp requires considerable slaked lime of ordinary quality, as the finely cut straw is digested with steam and slaked lime in a rotating cylinder converting the straw into a pulp.

Such an industry will likely be started in Manitoba as the raw materials are cheap and the market for the product is increasing.

MINOR USES.

Other uses for lime not specially applied in Manitoba are:—

The purification of gas from hydrogen sulphide and carbonic acid; the conversion of ammonia liquid from gas works into commercial ammonia; as a pottery glaze; in drying fabrics; as a polishing material for metals and glass; as a disinfectant; for the manufacture of bleaching powder and chloride of lime; for refractory bricks used in basic steel manufacture; as lime pencils for oxyhydrogen lights; in the manufacture of calcium carbide; for dehydrating alcohol; for preserving eggs; for making acetate of lime, a by-product from charcoal manufacture; in the manufacture of chemicals such as potassium bichromate, sulphate of ammonia, bone-ash; as a binding agent in the briquetting of finely divided ores and flue dust at metallurgical works; as a binder for coal dust and fine coal often pressed into fuel briquettes; in purifying raw sugar; as a fertilizer for farming land, stimulating the soil in many ways; in the manufacture of paper from rags, and other uses in the arts and manufactures.

VI.—LIMESTONE OCCURENCE IN MANITOBA BY DISTRICTS.

The present need of the Portland cement industry in Manitoba is a pure limestone, chalk or marl to combine with the calcareous shales of the Niobrara formation, which are found at several points from the Pembina River Valley on the International boundary up to the Porcupine Hills on the northern boundary.

The following descriptions are an attempt to give as far as possible the locality, extent and industrial value of the different limestone outcrops in each district convenient to transportation facilities. Some analyses have been collected from previous reports and many additional ones made for this report.

In judging the quality of the limestone as a raw material for Portland cement and other industrial uses, as shown by the chemical analysis, it is well to note that the present standard and requirements for raw materials may be changed as engineers and research chemists are constantly striving to reduce the costs and raise the quality of cements and other products made from limestones.

The different outcrops are given by numbers to correspond with the table of analyess and it is convenient to place them in the following groups:—

(1) Tyndal district, from East Selkirk eastward.
(2) Stonewall district, north of Winnipeg to Teulon.
(3) Lake Winnipeg district, including all the deposits on the west shore and on the islands.
(4) Lake Manitoba district, including the outcrops on the shores and islands.
(5) North-Western Manitoba district, including the outcrops on the shores and islands of Lake Winnipegosis.
(6) Miscellaneous deposits.

Some of the deposits show interesting scientific geological features, but for this report the following points are considered sufficient:—

(1) Location and transportation facilities.
(2) Mining or quarrying facilities.
(3) Physical quality of the deposit.
(4) Chemical composition of the material.
(5) Industrial value.

The geological relations of the limestone deposits of Manitoba have been carefully worked out by Messrs. J. B. Tyrell and D. B. Dowling of the Geological Survey Department and the published reports (1890-91, 1898) together with the excellent maps prepared by the Topographical Branch affords a convenient guide to parties interested in the practical uses of limestones in Manitoba.

TYNDAL DISTRICT.

The quarries near Tyndal are similar in section and composed of the following strata in descending order, showing an unlimited supply of stone as the known area of high grade stone is about 3 square miles:

Surface boulder clay with broken limestone boulders.	3 to 10 feet.
Thinly bedded, rather friable limestone, used for rubble and lime.	4 feet.

Excellent building stone in layers varying from 1 to 3 feet in thickness	30 to 50 feet.

Henry's Quarry.—This quarry is located about 1 mile south-west of Tyndal Station, Canadian Pacific Railway, and a spur line runs into the quarry so that cars loaded in the quarry can be hauled to Winnipeg without re-handling. It has been worked for several years by William Henry & Company, of Tyndal.

A capping of two feet of surface soil and three feet of broken stone covers horizontally bedded, tough, compact, fine grained mottled limestone belonging to the Upper Trenton formation. The mottled effect is due apparently to irregular concretions of brownish-red limestone imbedded in the matrix of softer and cream-colored limestone.

The quarry is equipped with steam derricks so that large blocks of stone may be loaded directly to flat cars on the spur line. Steam drills and hand drills are employed, blasting being done by giant powder. For making rubble blasting is done by dynamite. The quarry shows a working face about 15 feet thick and the horizontal beds running from 10 inches to 5 feet in thickness are worked by benches and show a large supply of available stone.

The quarry produces dressed and rough building stone, such as lintels, sills, corners, coursings, footings, coarse and fine rubble for concrete and ornamental dressed stone, such as grave-stones. A high grade white, quick-setting quicklime is also produced from four pot kilns built up on one side of the quarry, as seen in Plate No. 1. It is widely used in Manitoba for mortar and as a plaster for the interior of buildings.

The owner reports the following output for the season of 1903 (March 15th to December 1st):—

Cut stone	150 cars.
Rubble and dimension stone	3 cars per day.
Lime	1 car per day.

Garson's Quarry. — This extensive quarry is located one-half mile west of Henry's Quarry on the same spur railway line running into Tyndal Station. It is owned and operated by the Garson Quarry Company of Winnipeg.

The surface level of this and the adjacent quarries is only 20 feet above the surrounding prairie level.

The quarry has been worked to a depth of about 70 feet from the surface and is about 500 feet long and 250 feet wide. Below this depth the stone is said to be friable. The north face of the pit shows a vertical, fairly regular surface formed by a fault in the bedded stones so that blocks are easily removed without blasting.

The north face shows the following layers in descending order:—

Black clay loam	2 feet.
Clay, gravel, limestone boulders	4 "
Broken limestone	10 "
Eight well defined layers of bedded stone varying in width from 2 to 6 feet	40 "

The beds are practically horizontal, having only a slight dip towards the west.

The west face is being worked out by benches, nine well defined layers being visible, as shown in Plate No. 2. The south face is perpendicular owing to a vertical crack parallel to the north face, but narrowing as it proceeds westwards. Practically the same layers are visible as on the north face. The east face is more or less perpendicular, having been formed by blasting. The south-east corner is taken up by a battery of four draw-kilns built on the face so that two sides of the shaft consist of solid bedded stone, the third being solid masonry.

Each kiln is elliptical in section, about 40 feet high, with the mouth of the vertical shaft on a level with the surface so that carts can dump directly into the shaft which is lined with fire-brick. The quicklime is drawn off at the bottom, carried in wheelbarrows to the hoist and dumped into box cars on the railway track at the top of the hoist. The burning is said to take seven days, using poplar and tamarac as fuel. The product is an excellent grade of strong, white quicklime, finding a ready sale.

The quarry is equipped with three horse-power derricks and three steam-power derricks for handling stone and rubble from the quarry to the cars. A steam-power lathe is used for turning out ornamental shapes and pedestals. At the time of inspection three steam rock drills were in operation and 68 quarry men and 30 expert stone cutters were engaged.

The stone as seen in the quarry has a uniform fine-grained, compact texture, with little evidence of soft spots, streaks of sand or fine irregular cracks. (The stone comes out in layers from 2 to 6 feet thick and fossil structures are often seen.) The dark brown spots imbedded in the creamy matrix give the stone a beautifully mottled appearance.

This quarry, together with the Garson Quarry at Little Stoney Mountain, produced the following for the season of 1903, according to the owner:—

Dimension stone	150,000 cubic feet.
Cut stone to the value of	$60,000
Rubble	8,000 cords.
Crushed stone for concrete	5,000 cubic yards.
Lime	150,000 bushels.

Gunn's Quarry.—This quarry is located 300 feet south-east of the Garson Quarry alongside the spur railway line running into Tyndal Station. It is owned and operated by John Gunn & Sons, Winnipeg.

The stone is practically of the same grade as the Garson Quarry, but certain layers having reddish spots are softer and more friable than the stone having the bluish-gray spots.

The quarry has been opened to a depth of about 40 feet and practically the same beds are to be seen as in the Garson Quarry. It is well equipped with steam and horse derricks. Channelling machines and about 30 quarry men are employed.

Another quarry is being opened by the same company at a point between this quarry and Henry's Quarry where the stone appears to be of a better quality, being free from the layers of friable, reddish limestone already mentioned.

The production of the quarries owned by John Gunn and Sons at Tyndal, Stoney Mountain and Stonewall is given by the owners for the season of 1903 as follows:—

Dimension stone	100 cars.
Rubble	10,000 cords.
Crushed stone for concrete	7,800 cubic yards.
Lime	250,000 bushels.

The lime is produced at this quarry by two modern draw kilns, as shown in Plate No. 3. Tram cars carry the crushed stone from the quarry to the top of the draw kilns, while the lime is drawn from the bottom and carried by wheelbarrows to box cars on the spur line.

Cutter's Quarry.—This abandoned quarry was formerly operated to produce lime and rubble. It is located about one mile south-east of Henry's Quarry on Cutter's farm.

The stone as seen by the small exposure resembles the stone at the other quarries, but seems to be slightly softer and not so well bedded.

Little's Quarry.—This abandoned quarry, formerly worked to produce lime and rubble, is located about 1½ miles south of the Cutter Quarry and about 4 miles south of Tyndal Station.

The limestone appears as a small hill having an area of about ½ acre and the highest point being about 30 feet above the surrounding prairie level.

It cannot compete with the Tyndal quarries as the nearest railway is about 2½ miles distant. It is stated that the new electric tram line running from Lac du Bonnet to Winnipeg will pass close to this quarry.

Sinclair's Quarry.—This small quarry is located about 2 miles directly north of Tyndal Station and is worked to produce lime by calcining the stone in two pot kilns built on the face of the quarry.

The limestone is fine grained, compact, rather soft, mottled, resembling the Tyndal stone but the beds are not so thick and the stone seems more friable.

It is found as a small hill about ½ acre in extent, the highest point being 30 feet or less above the surrounding level. Two small adjacent quarries locally known as *Mangar's Quarry* and *Gerard's Quarry* also produce lime in small quantities. Small trees fit for fuel are abundant so that lime can be produced at low cost in crude pot kilns and sold at Tyndal Station for 21 cents per bushel.

Hick's Quarry.—Located at the village of East Selkirk, about ¼ mile from a spur line of the Canadian Pacific Railway, and is worked to produce lime and rubble.

The stone is beautifully banded and mottled, but seems to be softer than the Tyndal stone.

The following analyses show the composition of the limestone in the Tyndal district.

	(1)	(2)	(2a)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Moisture	0.08	0.03	0.03	0.10	0.09	0.13	0.06	0.09	—	0.07
Insoluble matter	0.74	1.20	0.90	1.08	1.08	0.90	1.20	1.06	0.91	1.15
Alumina and iron oxides	0.65	0.70	0.70	0.60	0.44	0.34	0.60	0.67	0.30	0.45
Lime carbonate	93.00	89.67	90.52	82.12	87.65	88.56	82.53	89.01	82.61	88.32
Magnesium carbonate	5.54	8.40	6.54	16.35	10.50	10.46	15.24	9.45	16.92	10.41
Sulphur trioxide	0.08	traces	0.14	traces	0.10	0.12	0.12	0.09	—	0.07
	100.09	100.00	98.83	100.25	99.86	100.51	99.75	100.37	100.74	100.47

(1) Average sample, Henry's Quarry, Tyndal.
(2) Average sample, Garson's Quarry.
(2a) Single specimen, Garson's Quarry, selected and analysed by the writer.
(3) Average sample, Gunn's Quarry.
(4) Average sample, Cutter's Quarry.
(5) Single specimen, Little's Quarry.
(6) Average sample, Sinclair's Quarry.
(7) Single specimen, Mangar's Quarry.
(8) East Selkirk limestone, report of Geological Survey Laboratory, 1882-84.
(9) Hick's Quarry, East Selkirk.

INDUSTRIAL VALUE AS SHOWN BY THE ANALYSES.

All of the limestones make a strong white or gray lime by using clean stone and proper methods of burning. The lime will be rather quick setting and should slake completely in a short time. It is now widely used in Manitoba for mortar and plaster but should find further uses in industries such as sand-lime brick, soap, tanning, puryfying city gas, lime-cement mixtures for mortar, plaster, brick, artificial stone, etc.

It carries too much magnesia for use in purifying alkaline water by the method used at the Winnipeg water-softening plant.

The limestone carries an excess of magnesia for use in Portland cement manufacture but is suitable for making sulphite of lime used in making chemical wood pulp and paper; for making common glass ware, such as bottles, insulators, etc.

STONEWALL DISTRICT.

The Stonewall Quarries. — The workable limestone at Stonewall is only from 8 to 10 feet thick, but the capping of boulder clay is light, being less than a foot in most places and is easily removed by scrapers, as the top of the limestone bed is made smooth by glacial action.

There are five quarries located north-east of Stonewall, forming a semi-circle around the village. The stone in all the quarries is practically the same and operations are confined to producing footings, rubble, crushed stone, fine dust for roofing material and white quicklimes. The stone is so much harder than the Tyndal stone that it cannot be cut at a profit.

In section the following beds in descending order may be noted:—

Boulder clay capping	6 inches to 2 feet.
Fairly hard limestone, strata varying from 2 inches to 1½ feet	8 feet.
Very hard, brittle limestone, used only for crushed stone.	3 to 4 feet.
Reddish shales	Unknown depth.

Plate No. 4 shows the natural conditions of the limestone and also the methods of working.

Both beds of limestone are of a dull gray color, fine grained, rather tough and compact but some layers are honey-combed with irregular pits filled with creamy-red iron oxides.

Portions of the stone appear to consist of irregular cream colored fragments cemented together by limestone of a more reddish color, giving the rock a mottled appearance but not so distinct as in the Tyndal stone.

This deposit seems to extend northward over a large area, as several exposures have been noted particularly on the N.E. ¼ section 4, township 15, range 2 east, about nine miles north-east of Stonewall and at a point on the C.P.R. about half-way between Balmoral and Teulon, where Mr. Dan Gunn is now opening up a quarry. The stone at this point is said to be a little softer than that farther south.

The following analyses show the stone to be dolomite of uniform composition:—

	(1)	(2)	(3)	(4)	(5)
Moisture	0.14	0.15	0.05	0.05	0.11
Insoluble	0.36	0.54	0.20	0.30	0.30
Alumina and iron oxides	0.35	0.35	0.30	0.30	0.30
Lime carbonate	53.53	53.90	54.40	53.90	54.43
Magnesium carbonate	45.81	44.24	44.98	44.78	44.56
Sulphur trioxide	0.13	0.12	0.13	0.11	0.13
	100.32	99.30	100.06	99.44	99.83

(1) Upper 8 feet in Fullbrook's Quarry, Stonewall.
(2) Lower 4 feet, Fullbrook's Quarry, Stonewall.
(3) Upper 8 feet, soft limestone, William's Quarry, Stonewall.
(4) Brittle lower limestone, William's Quarry, Stonewall.
(5) Gunn's Quarry, Stonewall.

This limestone, while of no value for cement, is excellent material for sulphite of lime and glass.

The quicklime produced at the Stonewall Quarries is a white, fairly strong lime, which finds a ready sale. It is probably slower slaking than the Tyndal lime owing to the higher magnesia contents.

It seems unsuitable for sand-lime brick and water-softening purposes, owing to the high magnesia contents, but should be useful for tanning and straw-board pulp.

The lime burners at Stonewall do not seem to appreciate the advantages of shipping their product as hydrated lime in the shape of a white, dry powder, as already described.* Probably the demand is so great that there is not much chance for the quicklime to spoil on their hands by hydration and reversion to carbonate of lime.

At the time of inspection the following quarries were in more or less active operation:—

Irwin's Quarry. — This quarry is located alongside the C.P.R. track about ¼-mile from the Stonewall Post Office and is owned by Peter Irwin & Sons, who have recently started operations. The stone occurs in thin, shelly, irregular layers, 3 to 8 inches thick, and is only fit for rubble, crushed stone and lime. At present the output is 200 cords of rubble per month, but a battery of pot kilns is being erected to produce 12,000 bushels of lime per month.

Fullbrook's Quarry.—This quarry is located adjacent to the C.P.R. track, directly east of Irwin's Quarry, and has an area of 30 acres, but workings are confined at present close to the railway siding. It is owned and operated by J. W. Fullbrook, but will shortly be controlled by the Winnipeg Supply Company, which is affiliated with the Ontario Lime Association and the Raven Lake Portland Cement Company of Ontario.

The layers of stone vary from 3 inches to 1 foot thick and the parting planes are very irregular so that the stone does not make good coursing stone, but is fit for footings, rubble, crushed stone and lime. The quarry shows a working face 9 feet thick.

The equipment consists of 1 steam derrick, 1 hand derrick, 2 pot kilns, 1 draw kiln and a crushing outfit delivering the product to flat cars on the railway siding.

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*Lime and Lime-burning.

The owner reports the output as follows:—

Rubble	25 cords per day.
Crushed stone	125 cubic yards per day.
Lime	4,000 bushels per week.

William's Quarry.—This quarry, located adjacent to and east of Fullbrook's Quarry, has an area of about 15 acres and is operated by E. Williams & Company, of Stonewall.

The quarry shows a working face 11 feet thick and the layers vary from 3 to 9 inches thick.

The equipment consists of 2 pot kilns and a crushing outfit delivering to flat cars as required the following sizes—3, 2 and 1 inch, used for concrete, and fines, which are sold as roofing material.

The owners report the outfit thus:

Rubble and crushed stone	300 cords per month.
Lime	6,000 bushels per month.

Patterson's Quarry.—This quarry, located adjacent to and east of William's Quarry, covers an area of about 35 acres and is owned and operated by A. Patterson & Company, of Stonewall.

The working face of the quarry is about 5 feet thick and the layers of stone are quite thin and irregular, varying from 2 to 6 inches thick. The stone is rather friable and fit only for rubble and lime.

One pot kiln is in operation.

The output, according to the owners, is:—

Rubble	25 cords per day.
Lime	4,000 bushels per week.

Gunn's Quarry.—This quarry, located east of the village but along the same railway line, has an area of about 40 acres and is operated by John Gunn & Sons, of Winnipeg.

The working face of the quarry is 8 feet thick and the irregular layers vary from 4 inches to 1½ feet thick, so that the stone is fit for coursings and footings, rubble, crushed stone, and lime.

The crushing plant is not yet installed. The lime is produced by one pot kiln and one draw kiln which is well arranged for cheap and effective service as a self-dumping mine car carries broken stone from the quarry over trestle-work to the top of the draw kiln.

The draw kiln is about 50 feet high, exterior measurements, and is built up as a square tower of partially dressed stone with a shaft lined with fire brick.

There are railway tracks on two sides of the kiln so that wood can be brought in on flat cars and unloaded near the fire box while the lime coming from the bottom of the kiln can be shovelled into box cars on the other track.

The output of this quarry is included in the figures given for Gunn's Quarry at Tyndal.

LITTLE STONY MOUNTAIN.

The quarries at Little Stony Mountain are only six miles north of the city of Winnipeg, located on a spur line of the Canadian Pacific Railway. There are two quarries operating:—(1) The Garson Stone Company's Quarry and (2) that of the city of Winnipeg.

The *City Quarry* has been sunk about 20 feet and stone has been taken off an area of two acres.

A section of the quarry is as follows:—

Boulder clay	1 to 8 feet.
Limestone, strata varyino in thickness from a few inches to 1½ feet	5 feet on east side. 16 feet on west side.
Soft brittle limestone, shown by borings	4 feet.
Soft shale, shown by borings	45 feet.

The limestone is of two kinds, (1) a cream colored, close grained variety near the surface, (2) a lighter colored, rather nodular, brittle limestone further down.

Chemical analysis shows both varieties to be dolomite:—

	Upper Limestone.	Lower Limestone.
Moisture	0.15	0.05
Insoluble	9.00	0.47
Alumina and iron oxides	1.35	0.41
Lime carbonate	49.09	54.33
Magnesium carbonate	40.26	45.06
Sulphur trioxide	0.14	0.13
	99.99	100.45

This quarry does practically nothing but crush stone for street paving. A few curb stones are cut, but the number is fast diminishing owing to the fact that cement concrete curb stones are cheaper and better.

The crushed stone is said to cost the city about $1.75 per cubic yard delivered in Winnipeg. The daily output of the quarry is given as 600 cubic yards of crushed stone which is screened into 4 different sizes: 2½ inch, 1½ inch, ¾ inch and fines.

The *Garson Quarry* is adjacent to the City Quarry, but little work has been done on it. The capping of boulder clay, about 6 feet thick, is being removed and the broken limestone found in the clay is sold as rubble.

STONY MOUNTAIN LIMESTONE.

Stony Mountain, located about 14 miles north of Winnipeg, is capped by a bed of limestone closely resembling the Stonewall variey, but carrying more iron and slightly softer.

Some parts of the limestone appear to be made up of angular, irregular fragments of cream-colored, compact, fine grained limestone cemented into a coherent mass by softer. reddish limestone.

Other parts of the bed appears to be of uniform composition, fine-grained, cream-colored, hard compact in places, but often honey-combed by irregular pits lined with reddish, soft, loose, calcareous matter.

The stone, as a whole, shows slight regular bedding, the layers being 3 inches to 1 foot in thickness, so that the quarried stone cannot compete with the variety quarried at Tyndal for use as a dressed stone. It makes excellent rubble with little power as the stone seems to crush easily, owing to seams of clay and its natural brittleness.

Gunn's Quarry.—This quarry, located on the north-west face of the mountain is operated by John Gunn & Sons, of Winnipeg, producing rubble and crushed stone.

The working face is 16 feet thick and is overlaid by only six inches of soil and debris. Some of the stone comes from the face in large blocks not entirely suitable for dressed stone owing to irregular cracks.

A spur line of the C.P.R. runs along the base of the mountain on the west side. A crushing outfit placed above the track delivers three grades of crushed stone, 1, 2 and 3 inch, to flat cars on the railway track. The fine dust does not appear to be used, possibly due to the amount of clay present. A draw-kiln, built of rough dressed stone, is built up as a square tower on the hill side and the top of the kiln is on a level with the floor of the quarry so that crushed stone is easily carted to the shaft of the kiln. The lime drawn out at the bottom of the kiln is shovelled directly into box cars on the railway siding.

The lime produced is of a gray color and rather slow slaking owing to high magnesia and siliceous contents and does not sell so readily as the better grades made at Tyndal and Stonewall at about the same cost.

Statistics of production are included in the report on the Tyndal quarry operated by the same firm.

On the top of the mountain, about ½-mile east of Gunn's Quarry, a new quarry is being opened up by the Manitoba Construction Company of Winnipeg, producing practically the same grade of stone as at the other quarry.

The quarry is about 45 feet deep and 100 feet square and is equipped with 2 steam drills and steam derrick loading rough stone and rubble to flat cars on a spur line from the Stonewall branch of the C.P.R.

The following analyses show the stone to be dolomite:—

	(1)	(2)	(3)
Moisture	0.05	0.05	——
Insoluble	11.65	5.10	0.08
Alumina and iron oxides	1.40	1.00	4.00
Lime carbonate	48.11	51.08	53.70
Magnesium carbonate	37.95	41.90	40.50
Sulphur trioxide	0.13	0.13	——
Undetermined	0.71	0.74	1.00
	100.00	100.00	99.28

(1) Lower Limestone, Gunn's Quarry, Stony Mountain.

(2) Upper Limestone, Gunn's Quarry, Stony Mountain.

(3) Limestone at Lower Fort Garry, reported by the Geological Survey Laboratory.

The analyses show that the Stony Mountain limestone is high in iron, alumina, siliceous matter and magnesia. The lime produced is gray in color and rather low grade in comparison with the Tyndal and Stonewall product.

LAKE WINNIPEG DISTRICT.

Along the west shore and on many of the islands in Lake Winnipeg the writer noted numerous outcrops of bedded limestone broadly classed according to location, structure and the contained fossils as belonging to the Ordovician period. The larger deposits close to deep water were examined to determine the value of the stone for building stone, rubble, lime and Portland cement. The completion of the Government locks at St. Andrew's Rapids on the Red River will allow loaded barges to travel from any of the deposits directly to the City of Winnipeg.

The outcrops north of Cat Head were not examined, as being too remote from the market and there is no chance for Portland cement manufacture at the north end of Lake Winnipeg as the cost of delivering coal is prohibitive.

The east shore of Lake Winnipeg consists largely of Archean rocks with no possible outcrops of sedimentary limestone. A reported deposit of crystalline limestone along the east shore north of Hole River was proved to be salmon-colored orthoclase felspar in a vein of pegmatite.

The shores of the southern portion of the lake are low and exposures of limestone in quantity were not noted.

On the north-east shore of Big Island bedded limestone outcrops near Hecla village and continues three miles along the shore towards Gull Harbor lighthouse, the highest point being 13 feet above the lake. The stone appears to be of uniform character, the layers being not more than 3 inches thick except at three points where they are 6 inches thick and apparently suitable for footings but hardly suitable for coursings in comparison with Tyndal stone. The stone is rather hard and brittle, often containing small cherty nodules so that some trouble may be encountered in dressing the stone. Fresh fractures show yellowish-gray, fine-grained, compact, rather brittle, non-crystalline surfaces, slightly mottled by irregular reddish and often dark blue patches.

North of Gull Harbor a cliff of creamcolored limestone overlying sandstone was noted, about 100 yards in length and 40 feet thick at the highest point of the cliff with about 20 feet of limestone exposed. The weathered surfaces are soft, crumbling, pitted and split into thin irregular layers from 2 to 6 inches thick, containing a few cherty nodules. Fresh fractures show yellowish-gray, fine-grained, compact, noncrystalline, slightly pitted surfaces, more or less mottled in appearance by reddish and often dark blue irregular patches. The stone is not suitable for coursings, but would make fairly good footings and rubble.

On the shores of Punk Island and on Deer Island are low cliffs carrying a 10 foot bed of dark, mottled, impure, cherty limestone breaking into irregular flags from 2 to 8 inches thick. Fresh fractures show dark, bluish-gray, compact surfaces. Some fairly good building stone may be obtained here but it will be hard to cut.

On Little Punk Island the bed of limestone lying above the sandstone and shale is much shattered and contains layers of sand so that it is of no commercial value except for rubble.

Grindstone Point is a cliff about 40 feet high, consisting of about 10 feet of friable sandy and flinty limestone overlying beds of greenish soft sandstone and shale. The limestone is useless for building purposes. A similar outcrop appears near Wells' saw-mill on Humbug Bay, but the limestone seems to be firmer and of fair quality for building purposes.

Bull Head consists of irregular broken flags of limestone at the base of a low exposure of thin-bedded, dark, mottled, impure limestone resting on sandstone. The stone is fit for rubble.

At Dog Head a buff colored limestone cliff is exposed to a height of 15 feet above the lake. The stone breaks into small irregular flags not more than 4 inches thick, so that it is fit for footings and rubble.

Limestone cliffs rise to a height of 10 feet above the lake on the north shore of Snake Island. The weathered surfaces show buff-colored, rather cherty, slightly pitted stone, breaking into irregular layers from 2 to 7 inches thick. Fresh fractures show grayish, fine-grained, compact, mottled surfaces with a few crystalline segregations. The stone is fit for foundations and rubble. The same bed rises about 9 feet above the lake on Black Bear Island.

At Little Tamarac Island a cliff 11 feet high along the north shore consists of thin-bedded, slightly-pitted, mottled, grayish-white and yellowish limestone, weathering an ashy-gray color and breaking into irregular layers about 4 inches thick. The stone is fit for foundations and rubble.

At the west shore of Jack Head Island a cliff, running 15 feet above the lake for a distance of 50 yards, consists of irregular layers of hard, mottled, dark-yellow with brownish-yellow and dark gray spots. The stone breaks into irregular lumpy fragments about 4 inches thick and is fit for foundations and rubble.

Cat Head consists largely of soft, crumbling, bedded, cherty limestone with a peculiar dark cream color on the weathered surfaces. The stone is fit for rubble.

None of the numerous outcrops north of Cat Head were examined.

ANALYSES OF LAKE WINNIPEG LIMESTONES:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Moisture	0.21	0.10	0.19	0.15	0.11	0.11	0.18	0.12
Insoluble	10.40	12.00	10.62	7.00	10.00	9.04	7.65	2.15
Alumina and iron oxides	2.10	2.70	1.90	1.68	1.70	1.70	1.50	0.80
Lime carbonate	76.44	74.88	72.57	82.23	75.97	77.61	79.35	74.52
Magnesium carbonate	11 05	9.72	14.36	8.99	11.48	10.46	10.40	22.00
Sulphur trioxide	0.09	0.10	0.24	0.09	0.09	0.09	0.09	0.21
	100.29	99.50	99.88	100.14	99.35	99.01	99.17	99.80

Dog head

(1) Average sample, south of Gull Harbor, Big Island.
(2) " " north of Gull Harbor, Big Island.
(3) " " Punk Island.
(4) " " Dog Head, west shore.
(5) " " north end of Snake Island,
(6) " " Black Bear Island.
(7) " " Bull Head, west shore.
(8) " " west shore of Jack Head Island.

INDUSTRIAL VALUE AS SHOWN BY THE ANALYSES.

The above analyses show that the limestones in the Lake Winnipeg district are of little commercial value in comparison with the varieties found at Tyndal and Stonewall, as they contain a large amount of siliceous impurities, iron oxides, alumina and magnesia and are unsuitable for Portland cement.

The lime produced by burning them will be grayish-white in color, containing more or less cherty nodules not slaking on the addition of water, and will show slight hydraulic qualities.

LAKE MANITOBA DISTRICT.

A careful search was made for outcrops of limestone on the shores and islands of Lake Manitoba as transportation facilities to all parts of Manitoba are available. The lake is deep enough to allow barges drawing 12 feet of water, the C.N.R. touches at Oak Point on the east shore also at the Delta on the south shore and the C.P.R. at the Landing on Whitemud River which is navigable.

The results show that beds of limestone fit for building purposes, rubble, lime and Portland cement are to be found along the shores. The shores of the southern portion of the lake are low and exposures of limestones were not noted, but are reported to be found below a slight surface capping of soil near Oak Point and 15 miles further north along the east shore of Lundyville.

The following table shows the average composition of the different outcrops of limestone examined:—

LIMESTONES IN LAKE MANITOBA DISTRICT.

	(1)	(2)	(2a)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Moisture.	0.18	0.09	0.11	0.19	0.05	0.09	0.13	0.05	0.07	0.04	0.05	0.05	0.05	0.05	0.08
Insoluble matter.	0.30	1.01	1.10	2.23	0.70	0.40	8.44	0.45	0.43	0.40	4.76	0.50	1.64	0.07	1.65
Oxides of iron and aluminum	0.50	0.35	0.20	0.80	0.50	1.90	7,35	0.44	0.45	0.30	1.00	0.28	0.73	0.28	0.32
Lime carbonate.	53.80	96.73	96.75	94.82	53.36	52.15	45.27	53.44	52.00	53.67	51.48	51.80	52.42	53.95	95.58
Magnesium carbonate.	45.55	1.38	1.51	1.87	45.11	43.96	38.90	45.00	47.00	45.56	43.00	47.00	45.15	45.36	1.28
Sulphur trioxide	0.08	0.08	0.09	0.14	0.06	0.11	0.09	0.08	0.11	0.12	0.11	0.11	0.08	0.09	0.09
	100.41	99.64	99.76	100.05	99.78	98.61	100.18	99.46	100.06	100.09	100.40	99.74	100.07	99.80	99.00

(1) The Quarry, Sifton Narrows.
(2) Steep Rock Point, east shore.
(2a) Steep Rock Point, special sample analysed by the writer.
(3) East shore, 1 mile north of Steep Rock.
(4) Outcrop on east shore, 2 miles west of Sowdust Island.
(5) Outcrop on Portage Road, 2 miles west of Sawdust Island.
(6) Outcrop on Portage Road, 3 miles west of Sawdust Island.
(7) Outcrop on east shore, 1½ miles south-east of Gypsumville.
(8) Outcrop on east shore, 1 mile south-east of Gypsumville.
(9) Davis Point, 50 feet back from east shore.
(10) Outcrop near road, 3 miles north of Gypsumville.
(11) Ridge, 3 miles north of Gypsumville.
(12) Outcrop on east road going from Gypsumville to the Quarry, about 4 miles from the village.
(13) Monroe Point, west shore.
(14) Onion Point, west shore.

Conclusions Drawn from the Analyses.—All of these limestones, excepting numbers 6 and 10, are fit for making a white lime for building purposes. Nos. 2, 3 and 14 should make a white, rich lime fit for sand-lime brick, water-softening, etc., where a pure lime is demanded. They are also fit for use in making Portland cement, generating carbonic acid gas for carbonating beverages, calcium carbide, etc.

On the east side of Sifton Narrows a low exposure of limestone was seen and about ¼ mile back from the shore limestone is being quarried by the Lake Manitoba Quarrying and Transportation Company, producing rough dimension stone, rubble, and a fine grade of white rather slow slaking lime made in pot kilns at the quarry, using wood as fuel. The stone occurs in thick, irregular beds and is a cream-colored, rather porous, fine grained dolomite. The stone is rather tough and does not take a dressed surface as readily as the Tyndal stone. A few crystalline segregations and also irregular pits are present.

The quarry is well equipped and a tram line runs from the quarry to a dock at the Narrows where the stone is transferred to barges delivering to C.P.R. cars at the Landing about 80 miles further south. The expense of handling the product to and from the barges is a serious drawback, preventing this quarry from being a strong competitor with the quarries at Tyndal and Stonewall.

At the north end of Manitoba Island a cliff of limestone about 12 feet above the water level runs fur 200 yards along the shore and seems to be a continuation of the outcrop at the Narrows except that the beds are thinner so that it is of little value for dressed dimension stone. Limestone of a similar character is reported to occur on the west shore of the Narrows, south-west of Manitoba Island.

On the west face of Point Richard a cliff of limestone about 10 feet high and closely resembling the outcrop at the Narrows was noted.

At Steep Rock Point on the east shore a cliff of upper Devonian limestone shows above the water level along the shore for about 300 yards, the average height being 14 feet. The weathered face of the cliff shows a tessalated structure due to the disintegration of the stone into small irregular pieces, proving that the stone is useless as a dressed dimension stone, but excellent material for rubble and crushed stone. Fresh surfaces show a light gray color, a sub-conchoidal fracture, a compact, fine texture with a few segregations of vitreous crystalline calcite. A continuation of the the same deposit was noted about 1 mile north of Steep Rock Point. This deposit is a valuable asset, with the following possible uses:—

(1) Burning into a high grade white lime in pot kilns built on the face of the cliff delivering the lime directly to barges unloading at Oak Point for the Winnipeg market and at the Delta and the Landing for the western market. The lime should be fit for mortar, plaster, sand-lime brick, tanning, water-softening, purifying city gas, etc.

(2) Shipping rubble and crushed stone to all parts of Manitoba for use in road-making, concrete, pavements, asphalt walks, etc.

(3) Shipping the rough stone for use in making Portland cement in combination with calcareous shales known to exist south of Morden, at Arnold and Leary's Siding on the Canadian Northern, at Sclater and other points along the C.N.R. in north-western Manitoba.

(4) Making Portland cement at some point on Lake Manitoba where suitable clay exists in sufficient quantity near transportation facilities. Clay was noted on the banks of the Fairford River and also on the banks of the Whitemud River near the Landing.

(5) If the beds of clay convenient to boat and railway transportation at Oak Point, the Delta and the Landing are fit for common brick, it should be a profitable business at these points to produce lime and common brick at one operation in Hoffman horizontal circular kilns using for fuel lignite coal fines which should be laid down at these points for $3.00 per ton, as the writer saw lignite fines going to the waste dumps at the Estevan coal fields for want of a market.

About 2 miles west from Sawdust Island, at the entrance to Fairford River, a reddish gray, pitted, semi-crystalline, fine grained limestone occurs in layers from 3 to 8 inches thick and weathers into smaller pieces of no value as a dressed stone.

About one-half mile back from the shore at this point a cream-colored, mottled, pitted, tough limestone occurs in irregular layers, about 3 inches thick, resembling closely the Stonewall limestone.

An attempt has been made to produce quarry stone from a bed of reddish, fine grained limestone located on the Portage Road running west from Fairford River at a point about 3 miles west of Sawdust Island. A test pit about 20 feet deep shows the stone to be of doubtful value as a dressed stone.

At Davis Point about 50 feet back from the east shore a creamy, fine-grained, pitted, tough, rather mottled limestone was noted in six layers, averaging 18 inches in width. The weathered faces show spalled and spitted structure indicating that the stone is hardly fit for dressed stone.

Outcrops of limestone resembling the Stonewall variety were noted at several points within a radius of four miles north and east of the village of Gypsumville, but the layers were thin and irregular, making the stone of doubtful value for dressed dimension stone.

At Monroe Point, on the west shore, three small cliffs are exposed close to the water's edge, showing light gray, tough, slightly pitted, non-crystalline dolomite in rather thick horizontal beds. Some fairly serviceable building stone may be obtained at this location.

Further west along the shore at Onion Point a cliff of limestone, 8 feet high, extends about 150 yards along the shore. The stone is light gray in color, fine grained, non-crystalline, compact and occurs in regular layers about 2 feet thick. The weathered stone seems to break into thinner layers with cross-fractures, destroying its value as a dressed stone.

LIMESTONE IN THE VICINITY OF LAKE ST. MARTIN.

Numerous exposures of thin bedded dolomites were noted on the islands and especially on the east shore of Lake St. Martin. The stone is generally yellowish-gray, fine grained and rather tough although more or less honey-combed with irregular pits. A few layers seem to consist of a mixture of bluish tinged stone imbedded in a creamy matrix. Such stone is hard, compact and suitable as a dressed dimension stone. The horizontal layers vary in width from 4 inches to 2 feet. In general the deposits may be said to closely resemble the Stonewall variety.

Lack of convenient shipping facilities renders the deposits of no commercial value. Samples were taken from several outcrops, the composition of which is shown by the following analyses:—

LIMESTONES AROUND LAKE ST. MARTIN.

	(1)	(2)	(3)	(4)
Moisture	0.12	0.20	0.20	0.05
Insoluble	7.84	0.42	1.20	0.64
Alumina and oxides of iron	0.36	0.67	0.60	0.45
Lime carbonate	49.25	52.18	53.85	54.12
Magnesium carbonate	42.68	47.00	44.12	45.00
Sulphur trioxide	0.14	0.11	0.09	0.08
	100.39	100.58	100.06	100.34

(1) Limestone bed, east shore, claim of R. McDonald, Fairford.

(2) East shore, L. St. Martin east of Dunsekika Island.

(3) " " opposite to Fisher Island.

(4) Island in Lake St. Martin, north of Fisher Island.

The analyses show that all of the limestones except No. 1 will make a fair grade of white lime suitable for mortar and plaster. None of the samples are suitable for Portland cement.

LIMESTONE IN NORTH-WESTERN MANITOBA.

The advent of the winter season (December 1st) and the exhaustion of the allowance for field expenses prevented the writer from inspecting this district.

Mr. R. T. Hodgson, science master at the Brandon Collegiate Institute, acting as assistant, was commissioned to report on this district, but after inspecting Riding Mountain was obliged to resume his school duties.

Through the courtesy of the officers of the Geological Survey, the writer had access to the excellent collection of fossil-bearing limestones from this district collected in 1889 by Messrs. J. B. Tyrell and D. B. Dowling from a purely geological standpoint.

Knowing the chemical composition of the upper Devonian limestone at Steep Rock Point, Lake Manitoba, and the correlated limestone outcrops in north-western Manitoba, the writer selected seven samples from outcrops convenient to transportation facilities which were thought to be suitable for Portland cement.

The analyses, as further shown, prove that the deposits of upper Devonian limestone in north-western Manitoba are suitable material for the manufacture of Portland cement and as such are a valuable asset. Many of the outcrops convenient to transportation are suitable for rough building stone and rubble, also for burning into high grade white lime for local use.

ANALYSES OF LIMESTONES IN NORTH-WESTERN MANITOBA.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Moisture	0.03	0.03	0.04	0.05	0.07	0.06	0.04
Insoluble	3.25	0.65	1.70	1.40	1.65	5.45	5.00
Alumina and iron oxide	0.74	0.22	0.30	0.42	0.38	1.40	0.92
Lime carbonate	95.01	97.90	96.81	96.30	95.69	91.24	92.46
Magnesium carbonate	1.20	0.90	0.90	0.85	1.80	1.50	1.20
Sulphur trioxide	traces	0.04	0.04	0.08	0.06	0.05	traces
	100.23	99.74	99.79	99.10	99.65	99.70	99.62

all high grade limes

(1) Sample of fine grained, compact, rather soft, fossiliferous, upper Devonian limestone, collected by J. B. Tryell, 1889, from Hog Island, Swan Lake.

(2) Sample of gray, compact, rather soft, fossiliferous upper Devonian limestone, collected by J. B. Tyrell, 1889, from Rosebush Island, Swan Lake.

(3) Sample of fossiliferous limestone similar to No. 2, collected by J. B. Tyrell, 1889, from Station 89, Swan Lake.

(4) Sample of creamy-gray, compact, rather soft, fossiliferous limestone from Mossy River, near Winnipegosis, where the projected C.P.R. line crosses the river.

(5) Sample of compact, rather hard, fossiliferous limestone, collected by J. B. Tyrell, 1889, from Snake Island, Winnipegosis.

(6) Sample of gray limestone containing numerous small, white fossil shells, collected by J. B. Tyrell, 1889, from Red Deer River, about 3 miles up from Lake Winnipegosis.

(7) Sample of hard, compact, brittle, upper Devonian limestone, collected by J. B. Tyrell, 1889, from Point Wilkins, Dawson Bay, Lake Winnipegosis.

LIMESTONES AND CHALK OF NIOBRARA FORMATION IN MANITOBA.

At the Western Portland Cement Works, Yankton, South Dakota, a high grade Portland cement is being made by the semi-dry process, using chalk of the Niobrara formation (Cretaceous) as a source of lime carbonate.

As the Cretaceous formations of South Dakota extend into Manitoba careful search was made for chalk deposits which were found at points as shown in the following table.

Outcrops of chalky, highly fossiliferous limestone, often charged with nodules of pyrite, have been reported from deposits in the Riding, Duck and Porcupine Mountains.

The following partial analyses show the composition of a few samples selected, in comparison with the chalk found at Yankton, South Dakota:—

	(1)	(2)	(3)	(4)	(5)	(6)
Moisture.	0.30	0.20	1.04	——	——	0.41
Insoluble matter.	1.24	1.00	13.10	18.77	4.24	3.00
Oxides of iron and aluminum.	1.16	0.72	10.09	16.28	4.75	1.50
Lime (CaO)	53.09	53.13	41.49	44.47	50.57	41.75
Magnesia (MgO)	1.07	1.27	0.63	trace	0.24	0.53
Sulphur trioxide (SO_3)	0.14	0.13	0.15	3.26	trace	21.16
Undetermined' (carbon dioxide) . . . (organic matter) . . .	43.00	43.55	43.50	17.22	40.20	31.65
	100.00	100.00	100.00	100.00	100.00	100.00

(1) Reddish, compact, soft, coarse grained limestone of Cretoceous formation, occurring as a bed about 2 feet thick on the banks of Assiniboine River, in section 36, township 8, range 11, west.

(2) Gray, rather soft limestone containing numerous white shells, found in layers from 1 to 4 inches thick immediately above No. 1. The whole bed is not more than 2 feet thick but outcrops at several points on the banks of the Assiniboine River.

(3) Finely divided, cream-colored, soft chalk of Niobrara formation found as a bed about 100 feet long and 12 feet high on a cliff facing the Pembina River in township 1, range 6, west, about 15 miles directly south of Morden. This deposit lies adjacent to calcareous shale.

(4) Yellow calcareous shale from a cliff in the Boyne Valley, near Leary Siding, C.N.R., in section 15, township 6, range 8, west. Analytis made by E. B. Young, Winnipeg, for the owners, Leary Land Company, Winnipeg.

(5) Niobrara chalk deposit, Western Portland Cement Works, Yankton, South Dakota. Analysis made by the writer on a dried sample from the deposit.

(6) Sample of loose chalk charged with decomposed pyrite and sulphates from a small deposit near the works of Pembina Portland Cement Company, Tongue River Valley, North Dakota.

INDUSTRIAL VALUE AS PROVED BY THE ANALYSES.

Numbers 1 and 2 are fit for Portland cement but present transportation facilities will not allow shipping to the cement works of the Manitoba Union Mining Company at Arnold, also to the projected cement works at Morden where it is proposed to make Portland cement from calcareous shale and the chalk (No. 3) which is hardly suitable for use for making high grade cement.

Lignite coal and fairly pure clay occur in alternate beds at Estevan, but high freight rates would prevent the use of this material at Estevan for making cement.

MARL DEPOSITS IN MANITOBA.

An examination of the ancient sea beach in south-eastern Manitoba showed that marl exists in many of the depressions and small lakes, but the marl is so intimately mixed with gravel and sand as to be worthless for any purpose except for back plastering of houses and closing cracks in houses and stables built of logs.

The marl located east of Gonor Station, C.P.R., is also mixed with siliceous matter and is not suitable for the manufacture of Portland cement.

Marl was noted in the bogs and lakes in the limestone areas in northern Manitoba. Small deposits are reported south of Carberry and near Baldur, probably due to the erosion of calcareous shales of the Niobrara formation.

The composition of a few samples selected is shown by the following analyses, proving that the marls are not fit for Portland cement:—

	(1)	(2)	(3)	(4)
Moisture	0.66	0.60	0.68	0.43
Insoluble (sand and clay)	1.18	35.40	45.70	36.50
Alumina and iron oxide	0.36	2.17	3.20	2.00
Lime carbonate	83.52	43.46	32.94	42.92
Magnesium carbonate	7.94	17.46	17.29	16.92
Sulphur trioxide	0.17	0.13	0.12	0.14
Undetermined	6.17	0.78	0.07	1.09
	100.00	100.00	100.00	100.00

(1) White marl from a lake east shore of Lake St. Martin, sample obtained by Roderick McDonald, Fairford.

(2) Cream-colored, loose sandy marl from a deposit east of Gonor Station, C.P.R., owned by Portland Cement Company of Manitoba, Winnipeg, recently organized to exploit the property.

(3) White marl mixed with white limestone pebbles and sand from a deposit located in the ancient sea-beach about 2 miles east of Saint Anne Station, C.N.R.

(4) Gray sandy marl said to be taken from a deposit in Assiniboia close to C.P.R. track, owned by H. Neep, prospector, Fort Francis, Ontario.

Search was made without the boundaries of Manitoba for deposits of cement making materials convenient to transportation and the following table of partial analyses of some of the materials examined shows them unsuitable for Portland cement:—

	(1)	(2)	(3)
Moisture	2.54	0.75	0.11
Insoluble matter	54.71	0.55	35.40
Iron and aluminum oxides	4.25	0.75	2.80
Lime carbonate	25.96	88.20	35.00
Magnesium carbonate	10.85	8.23	26.08
Sulphur trioxide	0.20	0.48	0.18
Undetermined	1.49	1.04	0.43
	100.00	100.00	100.00

(1) Clay marl from the shores of Rainy Lake, near Fort Francis, found as a layer about 1 foot thick.

(2) Marl found at the bottom of a shallow lake located above Limestone, Oliver Township, western Ontario, 3 miles from C.P.R. track.

(3) Compact, blue-gray, coarsely crystalline, ferruginous limestone with stringers of white crystalline calcite. The weathered surface resembles limonite. Found in abundance on the west shore of Steep Rock Lake, lower end nearest Atikokan Station, Canadian Northern Railway.

VII.—THE GYPSUM CEMENT PLASTER INDUSTRY.

Gypsum cement plaster, commonly known as hard wall plaster, is made at the village of Gypsumville on the north shore of Lake Manitoba by the Manitoba Union Mining Company, the annual product being 5,000 tons of hard wall plaster, finding a ready sale in western Canada.

The industry employs about 50 men steadily and is likely to expand when better railway facilities allow a reduction in the cost of production and placing on the market.

GYPSUM MINING.

The gypsum deposit is located about 12 miles north-east of Gypsumville and, according to the writer's observations, it extends over an area about two miles long and one mile wide. Borings at different points have shown it to be at least 50 feet thick and overlaid by only two feet of surface soil and debris so that an abundant and cheaply obtained supply of high grade gypsum is available.

Two openings have been made on high ridges to avoid water, the larger showing a working face 20 feet high and 500 feet long, with the following layers in descending order:—

(1) Yellowish soil and decayed vegetation	2 feet
(2) Finely divided, decomposed gypsum of a dirty cream color, useless for making plaster	2 "
(3) White, semi-crystalline, loose textured, soft gypsum in irregular, contorted, more or less horizontal layers with streaks and pockets of brownish, decomposed vegetable matter. A few large cavities are present with crystals of selenite on the walls	16 "

The smaller quarry is one mile east and shows a similar structure.

The ore is quarried by drilling with augers and blasting with 60% dynamite. Mining is done during the winter season to allow sleigh haulage on snow and ice over roads which are almost impassible in the summer season.

To avoid picking up fine earthy material and finely divided gypsum, which is used for the second-grade material for plates forks are employed for loading instead of shovels.

A tram line running from the mine to the mill is proposed, to reduce the cost of haulage.

GYPSUM MILLING.

The mill located at Gypsumville, is equipped to produce 50 tons of calcined gypsum per 24 hours and the working season only continues for about 150 days during the summer season.

The rock is carried from the stock piles by wheelbarrows, delivering to a jaw crusher passing rock 2 inch diameter and finer to a cone crusher delivering a product ¼ inch diameter and finer to a bucket elevator feeding a French horizontal buhr stone mill grinding the rock to 80 mesh and finer.

The pulverized gypsum is then calcined in a circular vertical kettle made by the Des Moines Manufacturing and Supply Company, using cordwood as fuel.

The kettle holds a charge of 10 tons which is heated and stirred till the mass reaches a uniform temperature of 280° Fahrenheit which is sufficient to remove a portion of the water of crystallization, making a material which will re-absorb water and recrystallize into a hard mass.

The calcined gypsum is discharged from the kettle to screens, finer material than 100 mesh going to a Broughton mixer while the oversize is returned to the buhr mill for regrinding.

In the mixer a patent retarder is added to prevent rapid setting of the plaster when water is added and goat's hair is added as a binder. The product is packed in bags holding 100 pounds and shipped to all parts of western Canada as hard wall plaster for the interior walls and ceilings of buildings af every description.

THE USE OF CALCINED GYPSUM AS A MATERIAL OF CONSTRUCTION.

Hard Wall Plasters.—The gypsum cement plaster as made at the Gypsumville Factory and as applied for interior walls and ceilings of the new Union Bank Building at Winnipeg has important advantages as a hard wall plaster over the lime plasters made in Manitoba.

Being a non-conductor of heat, it is useful in fireproof buildings. It sets and dries quicker than lime plaster and may be used in cold weather so that interiors of buildings where it is used may be finished more rapidly.

When mixed with 10% of lime and allowed to set, its hardness is greatly increased and it sustains a high polish and may be used for wainscoting as a substitute for marble.

Changes of temperature do not cause cracking or chipping of walls and ceilings, which may be soaked with water from leaking roofs without serious injury.

As a mortar for interior work it may be put directly on wire netting or expanded metal lath nailed to the studding. The gypsum mortar oxidizes the metal to some extent binding the mortar to the wire, but it will not proceed beyond the desirable point if the wall is normally dry.

The great objection to its use is the greater expense but the results are so much better that it is certain to be used more as its advantages become recognized.

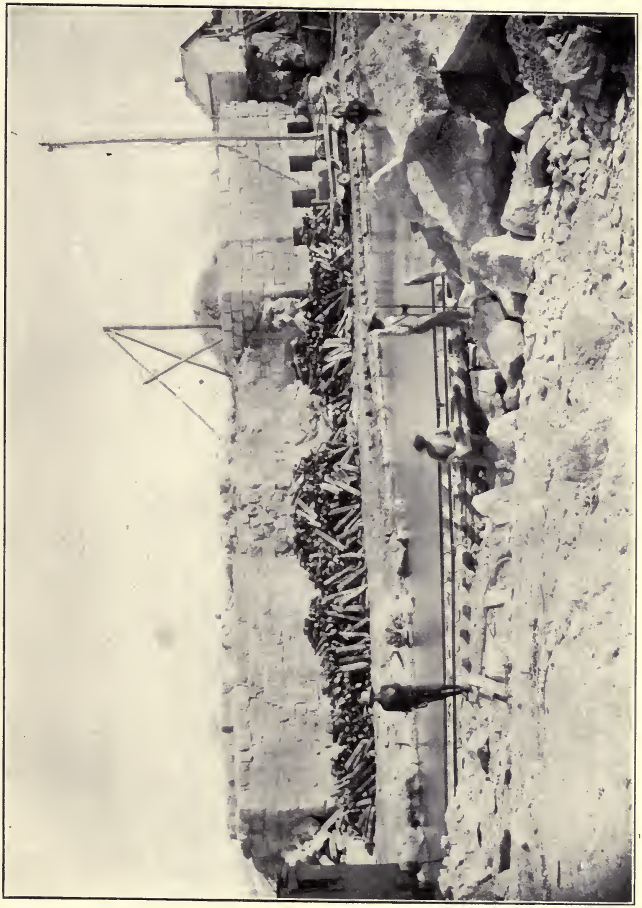
Plaster Boards for Walls and Ceilings.—Gypsum cement plaster is now being used in Canada in the form of fire-proof boards or sheets about 32 inches wide and 36 inches long, composed of alternate layers of strong wool felt or stiff paper and plaster. The boards may be sawed to any size required and nailed or screwed directly to wooden studding and are an excellent substitute for wooden lath and plaster in the construction of plastered walls and ceilings and for fire-proofing between floors, exposed wooden surfaces and under roof boards.

Such boards have been made and used for several years in Europe, both for inside and outside walls, using inside sheets of asphalt paper tacked to the studding over which the plaster boards are nailed. An outside coating of asphalt paint is sufficient for a protection against the weather.

There is an excellent chance for the introduction of these boards in buildings in Manitoba, replacing wooden lath for interior work, also weather boards and siding for outside work.

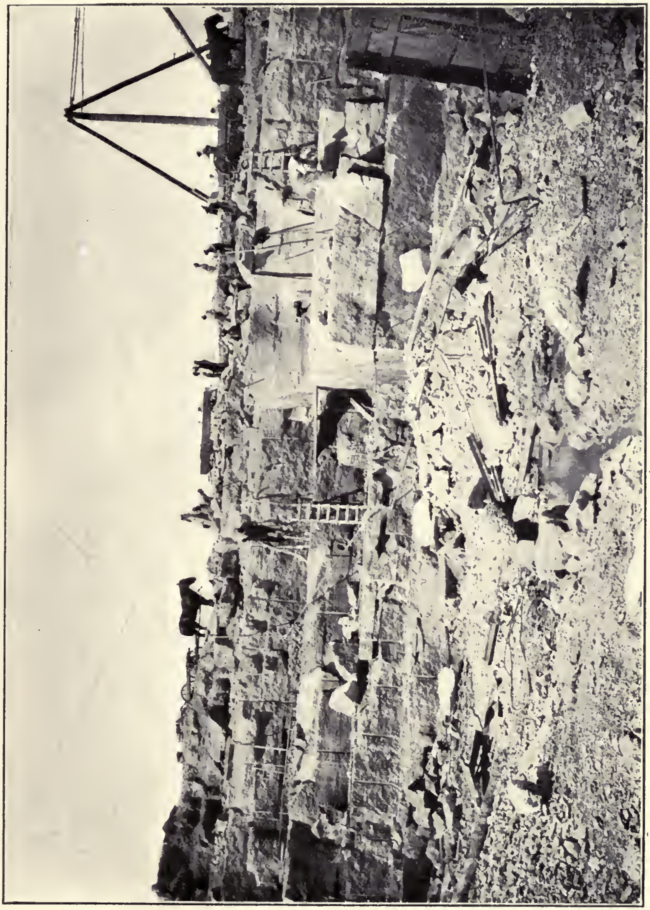
Floorings.—In German technical journals on building materials calcined gypsum of the variety known as "estrick" is recommended as a flooring material for factories, kitchens, bathrooms, store-rooms and hospitals. A German gypsum cement, which is said to be used for floors, consists of estrick gypsum, to which 0.4% calcined Glauber's salts (Na_2SO_4) has been added. This cement may be mixed with sand and ashes and is said to be unusually hard and durable, sets quickly and unites quickly with the material on which it is placed, usually sand, coal ashes, brick or wood. Its surface is slightly porous, absorbing but little oil when covered with paint.

PLATE 1.



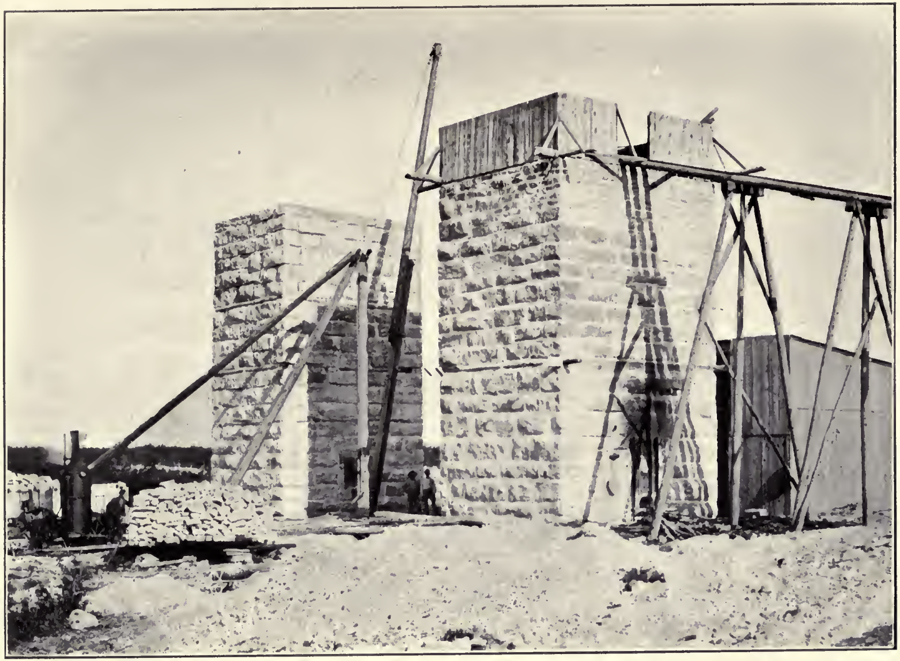
SHOWING THE POT KILNS IN OPERATION AT HENRY'S QUARRY, TYNDAL, ALSO THE CHARACTER OF THE QUARRY STONE.

PLATE 2.



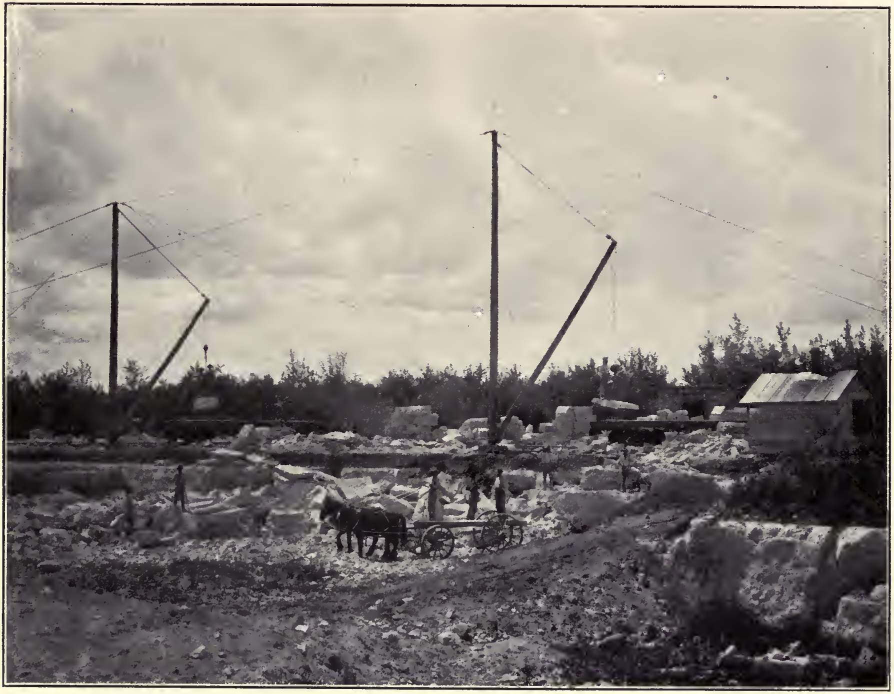
Photograph showing the character of the Bedded Limestone on the West face of Garson's Quarry, Tyndal.

PLATE 3.



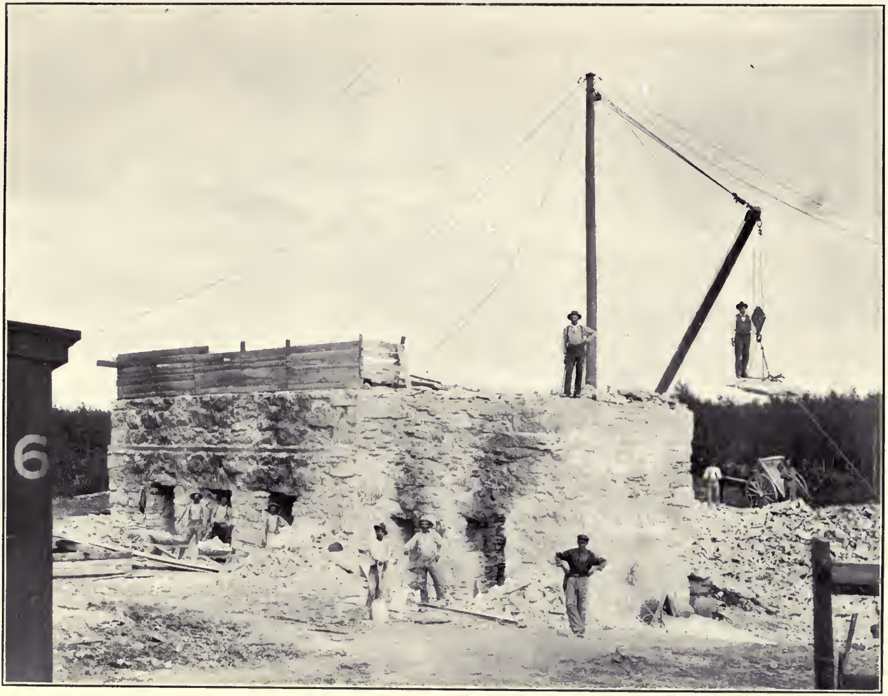
PHOTOGRAPH SHOWING THE TYPE OF DRAW-KILN USED AT GUNN'S QUARRY, TYNDAL.

PLATE 4



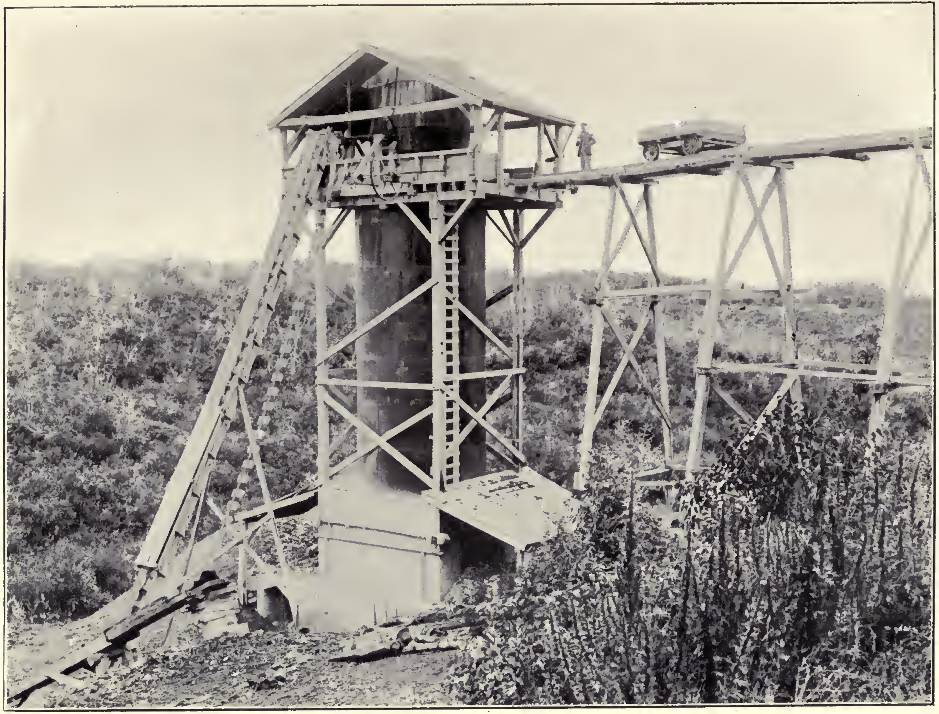
PHOTOGRAPH SHOWING THE CHARACTER OF THE LIMESTONE AT STONEWALL AND THE METHOD OF HANDLING THE QUARRIED STONE FOR BUILDING PURPOSES.

PLATE 5.



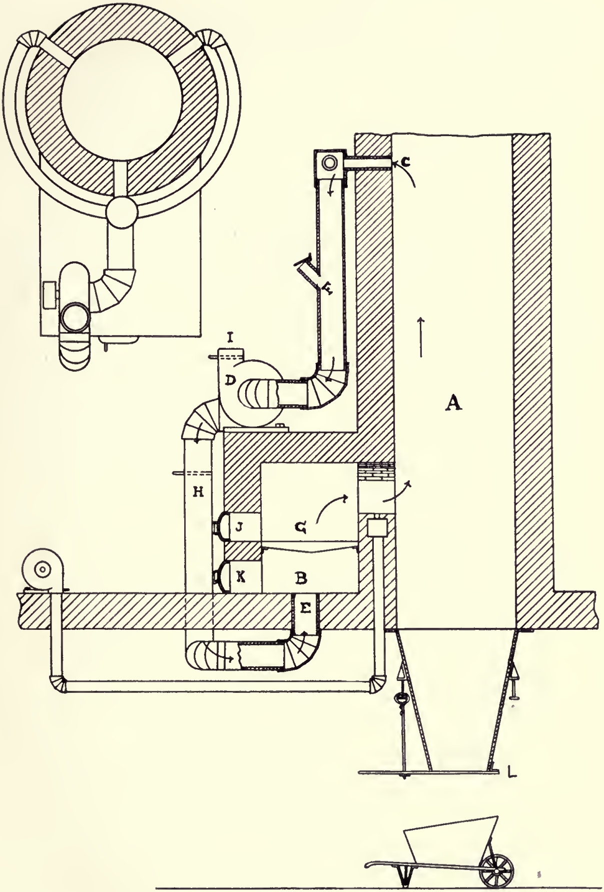
PHOTOGRAPH SHOWING THE STYLE OF POT KILNS COMMONLY USED AND THE METHOD OF HANDLING THE STONE AND BURNT LIME AT THE STONEWALL QUARRIES.

PLATE 6.



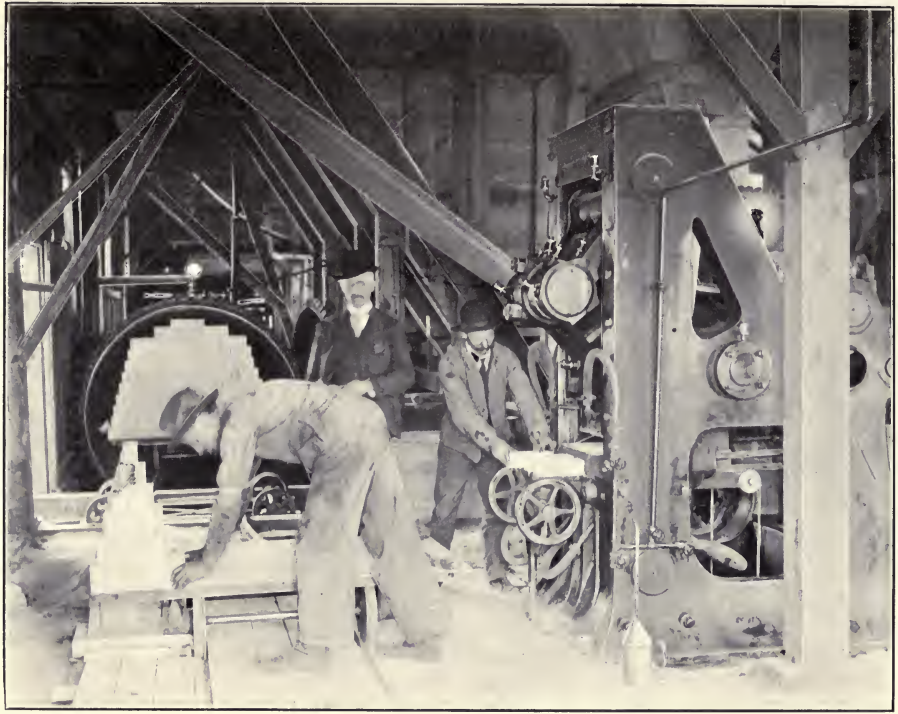
Photograph showing the style of vertical shaft lime kiln without a fire place. This particular kiln is used at the Arnold Cement Works, Manitoba, to produce natural cement from highly calcareous shale. The fuel (lignite) is delivered by the tram car as shown, while the cement rock is hoisted by bucket elevator. The product is delivered to tram cars at the bottom.

Plate 7.



Drawing showing a simplified vertical section of a draw kiln equipped with the Eldred process of flame regulation.

PLATE 8.



PHOTOGAPH OF THE INTERIOR OF THE BRANDON SAND-LIME BRICK WORKS, SHOWING THE BRICK PRESS AND THE CYLINDER FOR TREATING THE FRESH BRICK WITH SUPERHEATED STEAM.

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